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Armored Turrets Ready for Shipment.

Rolling an Armor Plate.

THE CENTENARY OF THE KRUPP WORKS.—[See page 136.]

The Earth's Atmosphere

Its Properties and Extent

By Arthur W. Ewell, Ph.D., Professor of Physics in the Worcester Polytechnic Institute*

THE chief constituent of our atmosphere is nitrogen, which in various compounds is the principal food of vegetable life. The vitally important constituent for animals is oxygen, which normally constitutes about 21 per cent by volume. In the most vitiated atmosphere the concentration may fall as low as 20 per cent, while human beings can only exist a few minutes if the percentage falls below 17, or only 4 per cent below the normal.

The constituent next in order of importance is carbon dioxide which varies from a thirtieth of one per cent in the open country to one third per cent in crowded halls, and two and a half per cent in mines. Green vegetation in sunlight absorbs carbon dioxide with the result that this component is somewhat less during the day than during the night. One of the chief functions of carbon dioxide and also of water vapor—a very variable constituent—is the absorption of radiant heat, enabling the earth to retain a considerable portion of the heat which it receives from the sun. At the same time they prevent a considerable fraction of the sun's heat from penetrating to the earth's surface.

The modernness of our knowledge of the surrounding air is illustrated by the fact that argon, which constitutes one per cent of the air about us, was not discovered until seventeen years ago. Helium, which constitutes one twentieth of one per cent, was discovered by the spectroscope in the sun some thirty years before it was identified in the air which we breathe. Among the more important rarer constituents of the air is ozone. There is practically none in crowded rooms, but in the open country the normal amount is about one part in a million, and after thunder storms there may be twice this amount.

Owing to diffusion, the air maintains approximately the composition above stated for several miles above the ground. The temperature for the first two miles obeys no general laws, and reversals are common, i. e., while on the whole the temperature decreases as one rises in the air, it may increase as one enters a stratum which rose from the earth some hours earlier, when the earth's surface happened to be warmer. Between elevations of two and seven miles the temperature decreases at the rate of about 20 deg. Fahr. per mile.

At the altitude of seven miles atmospheric conditions radically change. The temperature at this altitude has fallen to —67 deg. Fahr. Above this altitude the temperature does not decrease but remains close to the value just stated, at least balloons with registering apparatus have found such to be the case up to eighteen miles. This discovery was made nine years ago and almost simultaneously by de Bort of Paris and Assman of Berlin.

This elevation of seven miles is a transition level in other important respects. The composition of the air at any altitude can be calculated from the density of the air at this altitude and the composition at the earth's surface. Such calculation shows that above seven miles water vapor is never present in sufficient amount to be condensed, and therefore this is the theoretical limit of all clouds. Triangulation measurements of the highest cirrus clouds have shown that this is the actual limit. This is also the ordinary elevation of smoke from volcanoes. Whymper, the great mountain climber, graphically describes an eruption of Cotapaxi in the Andes, and he tells us how by comparison with known heights, he estimated that the smoke rose to the seven-mile level, and it ascended to this elevation in less than one minute.

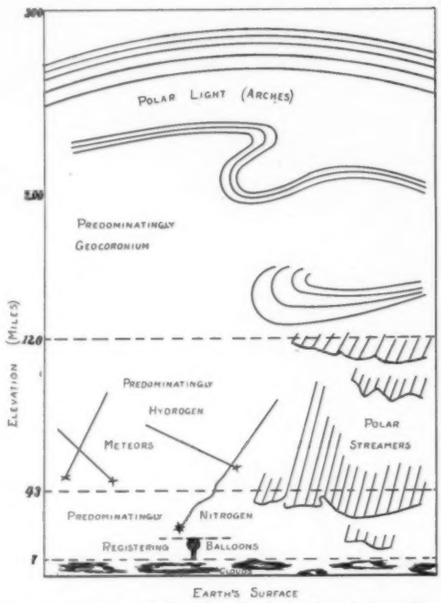


Fig. 1.—Section of the Earth's Atmosphere, According to Wegener.

Seven miles is also the elevation of the particles which form the first so-called twilight arch. After the sun has apparently disappeared in the west, we continue to receive light from the upper atmosphere which is still within the sunlight. As the sun sinks or rises, there are three distinct limits to the bright portions of the heavens. The first twilight arch disappears when the sun is eight degrees below the horizon, which corresponds to an elevation of about seven miles, as may be demonstrated by a simple mathematical proof.

Calculation from the laws of gases shows that between the elevation of seven miles and about forty-three miles, the relative amount of nitrogen is even greater than on the earth's surface. This is confirmed by the light from meteors, for when the meteors are traversing this region, the spectrum of the light is chiefly that of nitrogen. Visual spectroscopic examination of meteor paths is obviously impossible and only rarely have meteor paths been discovered upon photographic plates which were exposed for large groups of stars. However, a few observers have obtained good photographs, notably Profs. Pickering of Harvard and Blajko of Moscow.

Most meteors disappear before they enter the isothermal nitrogen atmosphere, i. e., before they are within forty miles of the earth's surface. The few which survive generally explode but the explosion may be delayed until within a few miles of the earth.

As we ascend higher, a second transition layer appears at about forty-three miles. The composition, calculated as previously described, shows that below this elevation nitrogen predominates and above it the atmosphere is largely hydrogen. This theoretical result is largely confirmed by the spectrum of meteors which above forty miles are distinguished by the prominence of the hydrogen lines.

Spectroscopic examination of the polar light shows this same change in spectra. This polar or northern light is undoubtedly due to so-called electrons, i. e., atoms of negative electricity which are emitted by the sun and are drawn into the earth's shadow by the earth's magnetic field. Free electrons cannot exist at pressures greater than 0.1 millimeter of mercury. This is the pressure at an elevation of about forty miles and the fact that no reliable observations have shown the northern lights below this height is a confirmation that the light is due to electrons. Until very recently all measurements of the height of the northern lights were very unreliable but recently Strömer has succeeded in photographing by exposures of only a few seconds, with extraordinarily sensitive plates, the same streamers or arches simultaneously from two points a known distance apart, and, from the difference in the two photographs, he has calculated the altitude by the well known methods of trigonometry.

Apparently hydrogen is incapable of producing the brilliant twilight colors for the last of the colors disappears when the sun is about seventeen degrees below the horizon, which corresponds to this elevation of about forty-three miles. A multitude of observations by different observers, at different stations widely distributed over the earth's surface have given angles lying between fifteen and eighteen degrees. It is interesting to note that the first recorded observations of this angle were made by Alhazen in Arabia in 1200 A. D.

The extraordinary bright evening cirrus clouds which followed the eruption of Krakatoa were in this border region between the nitrogen and hydrogen atmospheres. Krakatoa is a volcanic island between Java and Sumatra in the East Indies. The sea water apparently worked under the volcano and explosions occurred on August 26th and 27th, 1883, which buried half of the island under one thousand feet of water, and caused a tidal wave which drowned thirty thousand persons on other coasts, the island itself being uninhabited. In the years following the eruption the twilight colors all over the world were very brilliant and bright evening clouds appeared at an extraordinary height. Their intensity gradually increased, reaching a maximum in 1887, after which they faded away and after a few years totally disappeared. The nature of these clouds is still in great doubt. Wegener, to whom I am indebted for a great number of my facts, considers that they were water vapor. We have seen that under normal conditions water vapor cannot become saturated to form clouds above seven miles, but the conditions following the eruption were far from normal.

Further evidence of the transition at forty-three miles from a predominatingly nitrogen to a predominatingly hydrogen atmosphere comes from observations of the audibility of great explosions. It has been repeatedly observed that the most intense sounds, such as the dynamite explosion on the Jungfrau Railroad in 1908, the eruption of Krakaton, etc., have been audible in two zones, the first being a circle with the explosion at the center about twenty miles in diameter. The second begins at a distance of about eighty miles. Thus, there is a region of silence about sixty miles wide between the two zones of audibility. Von der Borne has found a very satisfactory and interesting explanation which substantiates the calculation of the pressure and composition at different heights upon which

* The author wishes to acknowledge his indebtedness to the papers of Alfred Wegener, Physikalische Zeitschrift, vol. XII, pp. 170, 214.

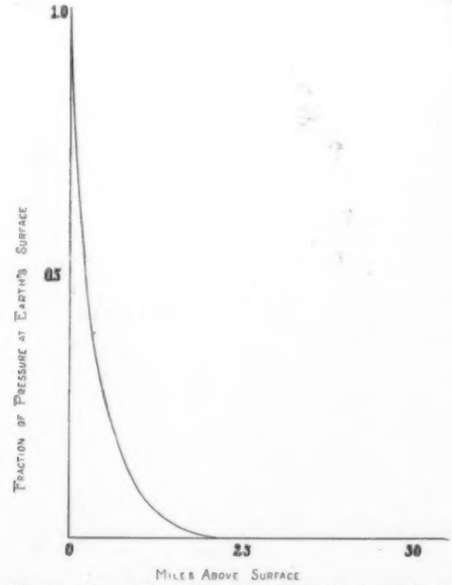


Fig. 2.—Curve Illustrating Decrease of Atmospheric Pressure as One Ascends From the Earth's Surface.

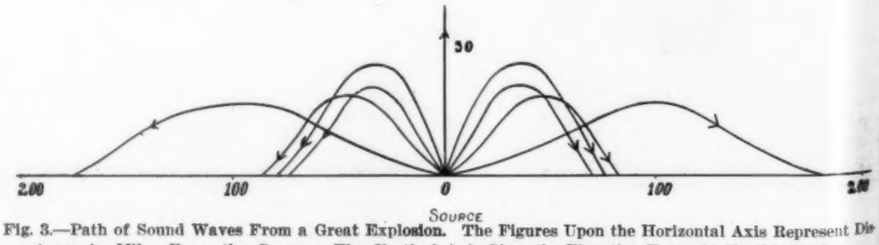


Fig. 3.—Path of Sound Waves From a Great Explosion. The Figures Upon the Horizontal Axis Represent Distance in Miles From the Source. The Vertical Axis Gives the Elevation From the Earth's Surface.

much of the previous discussion has depended. In outline his explanation is the following: When a sound wave passes obliquely from one medium to another, the obliquity is greater on the side upon which the velocity is the greater. The velocity of sound waves increases as the temperature rises but decreases if the gas mixture changes to one of higher mean molecular weight. Near the earth the composition, and hence, the molecular weight, is approximately constant, but the temperature decreases, therefore, the waves are bent upward. Above a height of about seven miles the temperature remains constant but the composition changes slowly toward a lower mean molecular weight. Therefore, the sound waves change their direction and may ultimately bend down toward the earth. The calculation shows that sound waves whose direction is within seventeen and one half degrees of the vertical do not return to the earth. If the angle is greater, they are bent down to the earth's surface, the nearest point at which the waves return to the earth's surface being seventy-two miles. Thus, the existence of this region of silence and the calculated location of its boundary agree remarkably well with the observed facts, and the detailed calculation strongly supports our hypothesis respecting the composition of the upper atmosphere.

For our knowledge of the hydrogen atmosphere, that is, the region above about forty miles, we must largely depend upon the spectra of meteors and the northern lights, and both show the hydrogen spectrum predominatingly in the region between about forty and one hundred and twenty miles. The visibility of the great majority of meteors is confined within this region. It is interesting to note that large quantities of hydrogen are often evolved upon heating meteors. The gas has apparently been imprisoned by surface fusion while the meteors were traversing the hydrogen atmosphere.

When we go above about one hundred and twenty miles the polar light spectrum is no longer predominatingly that of hydrogen but most of the light is of a wave length which corresponds to no element yet discovered upon the earth. This light is conspicuous in the spectrum of the upper portions of the polar streamers and forms about the entire light of the homogeneous arches which are at a much higher elevation, perhaps above two hundred miles. In fact, Paulsen, describing his remarkable series of observations in Iceland, states that upon alternately gazing at the arches through the spectroscope and with the naked eye, no difference in color was discernable, so homogeneous was the light, showing that the upper atmosphere largely consisted of this unknown element. Argon and krypton are the only elements having adjacent spectrum lines, but these are far too heavy to be present at this elevation. Therefore, Wegener, to whom I have before expressed my indebtedness, considers that this region is filled with a gas which has not been identified upon the earth and to which he gives the name of *geocoronium*.

In Mendelejeff's "Periodic Table of the Elements" the different elements are arranged in successive columns and lines, according to their atomic weights, the elements in any line or column showing striking similarities. To form the full lines and columns of this table, Mendelejeff was obliged to assume the existence of as yet undiscovered elements of intermediate atomic weights, and the properties of these hypothetical elements can be predicted from those of their neighbors. For example, most of the properties of the element which we now know as germanium were predicted by Mendelejeff before the element was discovered. Geocoronium must be lighter than hydrogen. In the zero column of Mendelejeff's table which contains the inactive elements helium, neon, etc., there is a lacking element whose atomic weight is four tenths that of hydrogen.

Wegener assumes that geocoronium is that element. He also assumes that at one hundred and twenty miles the atmosphere is half geocoronium and half hydrogen. This assumption is based upon the following facts: At this elevation the spectra of the two elements in the polar light are of about the same intensity. There is also evidence of a third transition in the atmosphere at about this height, for the very feeble blue which succeeds the twilight colors disappears with a depression of the sun corresponding to about this elevation. This elevation is also the upper limit of the heights at which meteors begin to be visible.

A natural inquiry is, why has not geocoronium been discovered in the atmosphere about us? This inquiry is readily answered by calculating the density at the earth's surface from the molecular weight, the calculated density of hydrogen at one hundred and twenty miles, and the assumption that it and geocoronium have the same density at this elevation. The concentration comes out six ten thousandths per cent, or below anything we could detect. How far does geocoronium extend beyond the earth's surface? We have two mere indications. The green polar light extends sometimes to heights of two hundred and fifty miles and during eclipse of the moon the shadow of the earth indicates that the atmosphere extends about two hundred miles above the solid ground.

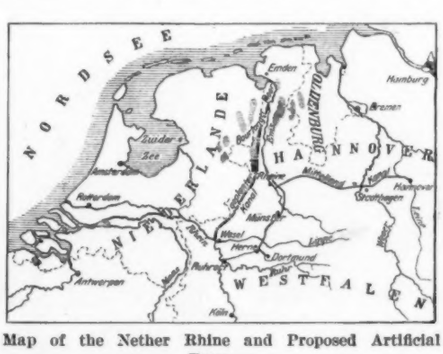
This hypothetical element, being lighter than any element known on the earth's surface, will escape in greater amount from the atmosphere. It is, therefore, very possible that this unknown substance which we see illuminated in the northern lights may be the most widely distributed substance in the solar system.

A Rhine-North Sea Canal

By Our Berlin Correspondent.

Of the total amount of goods carried each year by the seven most important German rivers, more than half (4,030 million mile-tons in 1905) fall to the share of the Rhine, which, by the way, shows an undoubted superiority over the three rivers next in importance, by the considerably longer duration of its average yearly navigability (Rhine 328 days, Elbe 300 days, Oder 282 days, and Vistula 260 days). In fact, the Rhine, in comparison with its limited navigable length (450 miles on German and 102 miles on Dutch territory), is from an economical standpoint the most important river in the world. As, however, this river nowhere communicates with the network of East-German waterways, while an efficient connection with the Weser has only recently been created, practically

Detail Map of the Proposed German Rhine Estuary.



Map of the Nether Rhine and Proposed Artificial Estuary.

the whole Rhine traffic—in so far as it is not of a local nature—goes to the sea, that is, to the Dutch seaports situated in the Rhine estuary, which are indebted for much of their present flourishing condition to the thriving industrial life of Germany.

In view of this state of affairs the idea of a German Rhine estuary has been suggested from time to time. It will obviously be of enormous importance for German economical life, if the Rhine where it bends off towards the Dutch frontier, viz., near Wesel, were to receive a canal branching along this frontier towards the nearest German sea-port, Emden or even as far as Bremen.

A comprehensive account of the technical possibilities of this Rhine-North Sea canal, recently prepared by two German government engineers, Messrs. Herzberg and Taak, gives some tangible data upon which to base an estimate of the competition such a canal would offer to the Dutch Rhine. According to the investigations embodied in this account the construction of this canal would be quite practicable. It would be 136 miles in length and would follow the tracé laid down in the map. It would be 14 to 16.5 feet in depth so as to afford small size sea vessels a ready access to the German portion of the Rhine navigable for such vessels. It is true that the ideal form of canal, viz., one having no locks, could not be realized, there being a level difference of 15 meters between Wesel and the terminal point, while a plateau of the Westphalian table-land 48 kilometers in length would have to be overcome between Bocholt and Gronau, at 131 to 164 feet height above the Rhine level near Wesel. This, however, would by no means make the canal incapable of competing with the natural estuary. Seven locks would be required, viz., two at the ends and five in the middle of the canal, of which one would be a double lock. However, the delay of ships traversing the canal, being only 0.62 of a minute per mile, would be relatively immaterial and quite negligible as compared with the advantages gained by the possibility for German shipping companies to convey, with a single train of sea lighters or barges, loads of 6,000 tons to and from the German Rhine land, without passing through Dutch territory.

It is contemplated to give the canal a breadth of 98 feet at its bottom, 184 feet at its water level, and 14.8 feet depth so that ships of up to 2,500 tons capacity could readily pass through. The locks are to be designed for a level difference of 18 or 30 feet. The building costs of the Rhine-North Sea canal are estimated at $58,750,000. While this enormous sum would charge each ton transported with 21c. (supposing 7,000,000 tons of the present Rhine-North Sea traffic to be diverted into the new canal), this would still enable the canal to compete with the Dutch waterway, the traffic directed toward the north and east enjoying the advantage of a shorter sea voyage from Emden. Moreover, it should be considered that the districts traversed by the canal could contribute considerably toward feeding the enterprise. There is, in fact, alongside the course of the canal, deposits of coal, iron ores, lime, clay, and rock salt, which are well worth exploiting. However, the canal would assume especial importance for the broad Bourtanger moors projecting between East Friesland and the Dutch province of Groningen, where extensive peat deposits could be exploited, while the canal by lowering the level of underground water, would open up new territories to agriculture. Finally, the Rhine-North Sea canal, especially if continued as far as the Elbe estuary, would possess a considerable strategical importance for the German navy.

Alcohol and Sugar from Palm Trees

Alcohol as well as sugar can be obtained from some of the palm trees in the extreme Orient. One of these is the palm known as *Nipa fruticans*, and there are three others growing in the Philippines which can be used, the *Cocos nucifera*, *Corypha elata* and another variety. The first of these is very abundant and its sap serves to produce a drink which the natives appreciate on account of its agreeable flavor. This is called cocoa wine and it has 20 to 50 per cent alcohol. During 1909 there were 28 distilleries engaged in treating 150,000 gallons of sap, which gave 20,000 gallons of a cocoa wine containing 37 per cent alcohol. This was entirely consumed in the country. The Corypha or Buri palm is very abundant at low altitudes, and the sap which is rich in saccharose is utilized by the natives in a fermented drink containing 10 to 16 per cent alcohol. Sugar is also made with the sap, as it has about 9 per cent sugar. From the same plant the natives extract starch as well. The Arenga is the well-known sugar palm of Java and India, but it is mainly used for producing a beverage from the sap, as this contains 17 per cent saccharose. The sap is use either fresh or after fermentation. From the pith of the palm the natives also extract a starch which is always more or less impure.

The Lake Near the Location of the Great Springs. Photo by Hrdlicka, Lent by the Smithsonian Institution.

A View of the Lake at the Head of a Canal, from "Seeing-Xochimilco" Boat. Photo by Hrdlicka.

Xochimilco and Its Lake of Gardens

Aztec Irrigation of the Sixteenth Century

By Carl Hawes Butman, Smithsonian Institution

To-day, with the help of modern engineering, we are taught how to regulate the flow of water through our gardens, farms and fields, for irrigational purposes; not only that, deserts, barren tracts and arid lands are claimed for garden and agricultural sites. We marvel at the trend of up-to-date science, its methods and results, and yet, as far back as 1521, just 29 years after Columbus discovered this continent, Cortez found that the Aztecs had a unique irrigation system of their own, which brought about remarkable results for them in the industry of farming.

How did they accomplish this, 391 years ago, when we are only just beginning to realize the value of systematic irrigation? They did it backwards. Instead of bringing the water to the land they brought the land to the water, building their farms in a lake. While this system probably originated some time previous to 1521, perhaps before the days of Xochimilco, it has been perpetuated by the natives of that town which now stands as its representative. Having been blessed with a lake of clear water at the edge of their village, the far-sighted Aztecs saw the need of good fields and gardens on which to raise their crops, and finding no land especially suitable, they proceeded to make land in the adjacent lake. With care and precision plans were laid, and islands of reeds or water-hyacinths and mud were built. These islands, though undoubtedly of an experimental nature at first, were soon made practical and eventually became indispensable as a source of food supply.

In regard to the historical significance of Xochimilco, Prescott, in his Conquest of Mexico, volume III, writes as follows:

"The point of attack selected by the general (Cortez) was Xochimilco, or 'the field of flowers,' as its name implies, from the floating gardens which rode at anchor, as it were, on the neighboring waters. It was one of the most potent and wealthy cities in the Valley, and a staunch vassal of the Aztec crown. It stood, like the capital itself, partly in the water, and was approached in that quarter by causeways of no great length. The town was composed of houses like those of most other places of like magnitude in the country, mostly of cottages or huts made of clay or light bamboo, mingled with aspiring *teocallis* (temples), and edifices of stone, belonging to the more opulent classes."

This old village still stands on the shores of "Lago Xochimilco," well named, "the field of flowers," distant about 15 miles from the City of Mexico, and is undoubtedly one of the few ancient Aztec towns in existence today. The cluster of little native cottages and huts, nestling among the ruins of the more pretentious edifices on the shore, forms the present town where perhaps 1,000 people dwell in perfect contentment. The Xochimilcans are of a friendly race, descending directly from one of the seven main tribes of Aztecs, which settled in the Valley of Mexico, and cherish a great love for their children and a passionate fondness for flowers. While the town is of considerable interest itself, it is far surpassed by the lake and the many cultivated islands it contains.

The peculiar origin and construction of the islands is unique and yet very simple from an engineering point of view. Some of the early Aztecs conceived the idea of building artificial islands which they termed *chinampas*. They did this by sinking bundles of reeds and water-hyacinths gathered from the shores of the lake, so as to form submerged rafts which served as foundations. Over these rafts dirt and alluvial soil were placed, and more brush and dirt piled on, until actual islands began to appear above the surface of the lake. In the rainy season, the islands sometimes actually floated but they were readily secured again and anchored securely. It was better at least, to have an island float away intact, with the crops still flourishing, than to have it flooded and the

Native Houses in the Village of Xochimilco, Showing Cactus Hedge. Photo by Hrdlicka. Lent by Smithsonian Institution.

View Showing Traffic To and From Market, On a Main Thoroughfare. Photo by Hrdlicka.

An Island-field of Corn, With Boatman Poling an Empty Dugout. Photo by Hrdlicka.

crops ruined. To prevent the shores from washing away or caving in, trees were planted along the edges, so as to form firm banks and boundaries, the roots tending to bind the soil and reeds firmly together. From year to year this artificial land sank gradually, owing to the deterioration and shrinkage of the vegetable matter in the foundation. After several applications of the reeds and dirt, however, a substantial piece of land was formed, which proved exceptionally fertile for farming.

Despite the fact that the farms were in the lake, it was found necessary to irrigate the crops to a certain extent and for this purpose long handled dippers were used by the farmers to throw the water upon the cultivated tracts. By watering in this manner, first from one shore and then another, making a complete circuit of the island, they were able to cover the whole area. Like all the other methods connected with this old system, that of hand watering is still followed.

Many of the islands still exist; all of them built in the same style but vary in size from 40 to 120 feet square, nearly every one verdant with crops of corn, beans, other vegetables or flowers. The foliage runs riot in colors, the shores are edged with tall green trees, and the waters near at hand are gay with bright tropical water lilies. All of which is clearly reflected by the mirror-like waters on the shores, until the beautiful scene is doubled; the whole presenting a picture of wonderful color and life, which delights the eye of the visitor as would the paradise of Eden.

Immediately in front of the village the lake opens into a broad expanse, forming a sort of bayou or water market-space from which the grand canal and other water causeways lead among the flowering island-fields, and intersect the cross canals and by-ways. Not far from this lagoon, in the corner of the lake nearest the mountains, are two *ojos* or springs set in deep regular cauldrons from which an enormous quantity of water is constantly gushing forth. In the neighborhood of these springs the water is very deep and surprisingly clear and cold. When passing over the pools in one of the little native canoes, it is hard to realize that one is not floating in an exceptionally clear atmosphere; the sensation is very unique, to say the least. Looking over the side of the boat, the topography of the lake bottom is seen distinctly, as well as the beautiful plume-like vegetation, and the broken pottery and other objects cast into the water by the natives as offerings to the Spirit of the lake. This offering of sacrifices is in pursuance of a custom that originated many years ago, at least before the destruction by the Spanish, of the Aztec image of *Sahagun*, the lake spirit, which rested far below the surface of the waters on the bed of the springs.

Laid off, as the islands are, in a most regular manner, they lend a Venetian-like appearance to the landscape, each blossoming individual garden separated from the others, by canals or water-lanes through which the canoes and dugouts of the native pass on the way to and from market. The regularity of the water-ways resembles the precise arrangement of the streets of a city; the main thoroughfares being from 40 to 50 feet in width, while the smaller ones, corresponding to alleys, are narrower, only wide enough to permit the passage of two boats. None of them is deep and consequently the native crafts are propelled by poles. An attractive feature is the artistic effect of the trees, which tends to break up the low and flat appearance given by the smaller plants and shrubs, thus relieving an otherwise monotonous landscape. Nearly all the trees are willows of a tall and slender species, resembling our northern poplars, and rise above the island-farms with a certain independence which seems to lend dignity and a sort of security to the general aspect.

The modern construction and repair of the islands is the same as heretofore; the old and original methods seem to prevail through lack of better or more expeditious ones. As at the beginning of the continent's history, the Aztecs hold the town and the lake in their own right, and it proves to-day, as Cortez remarked nearly four centuries ago, not only a thrifty village but a most attractive one as well—the houses and cottages on the shore, the farms and garden plots in the neighboring lake.

In 1910, while returning from explorations in Peru, Dr. Ales Hrdlicka, of the United States National Museum, stopped at the City of Mexico and made a trip to Xochimilco where he carried out some interesting studies along the line of physical anthropology, taking several casts of native heads.

A fine feature of his trip was a sail through the canals of Xochimilco, in a native "sight-seeing" boat from which he took a number of the pictures. He states that he was amazed by the quality of the vegetables and the beauty of the flowers, and that both the vegetables and flowers were remarkably cheap. A brief review of Dr. Hrdlicka's researches, is found in a report on the explorations of the Smithsonian Institution carried on during the years 1910 and 1911.

Porous Metals

A New Material for Accumulator Plates

By the Berlin Correspondent of the Scientific American

Among the various alloys of two metals, those termed "eutectic" occupy a special position. The melting point of such an alloy is the lowest of all the temperatures at which the various alloys of the same substances pass into an entirely molten condition.

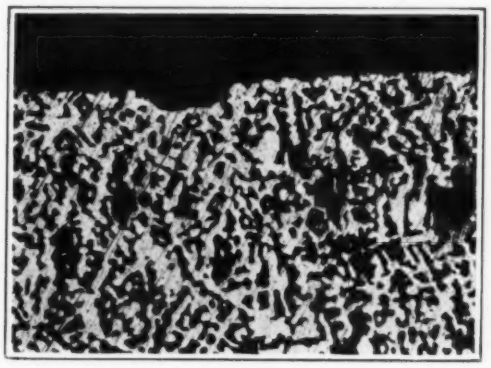
As the composition of "eutectic" alloys is constant, they were formerly considered to be chemical compounds. F. Guthrie, in 1884, was the first, by a systematic investigation, to elucidate what had formerly been known only by occasional and incorrectly interpreted observation. Guthrie examined metal alloys as well as salt mixtures and aqueous salt solutions, pointed out many analogies, and showed eutectic mixtures to be mechanical mixtures rather than chemical compounds, a conclusion which was subsequently confirmed by microscopic observation.

Lead-antimony After Expulsion of the Eutectic Alloy.

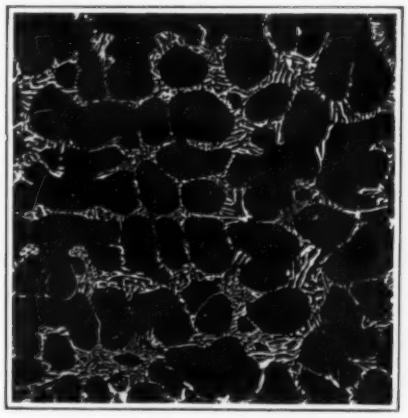
In the case, for instance, of lead-antimony alloys, the solidified eutectic mixture, consisting of 87 parts of lead and 13 parts of antimony, was under the microscope, found to consist of alternate films of lead and antimony. All other alloys can be considered as mixtures of the eutectic alloy with an excess of lead or antimony respectively. When a molten alloy containing, say 50 per cent of antimony, is cooled down, it is found to congeal at many points of the liquid, until at 228 deg. Cent. any remaining molten metal solidifies with the composition of the eutectic alloy. If the molten mass contains more lead than corresponds to the eutectic alloy, the surplus lead gradually solidifies, until only the eutectic alloy is left, which then congeals in bulk.

If a poured plate containing 96 per cent of lead be cooled down, an increasing number of lead crystals form and these gradually coalesce into a compact mass, with the molten remainder of the metal contained in millions of inter-communicating canals. As the temperature reaches 228 deg Cent., which is the melting temperature of the eutectic alloy, these canals suddenly pass into a solid condition. They contain the whole of the antimony, viz., 4 per cent, and a quantity of lead given by the condition that the eutectic alloy contains 87/13 times as much lead as antimony.

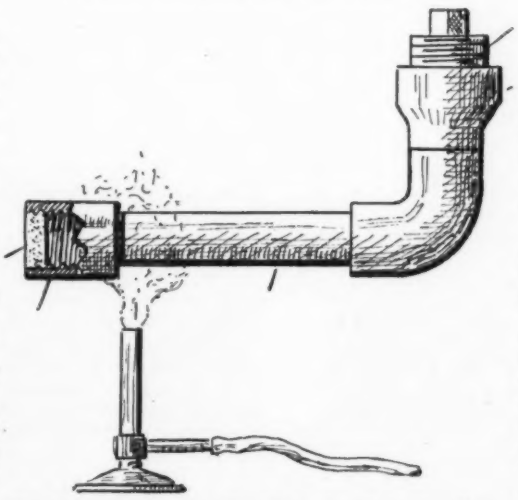
The amount of lead accordingly is $\frac{87 \times 4}{13} = \frac{348}{13} =$ about 27 per cent, and $96 - 24 = 69$ per cent of lead have become solid before the congelation of the canals.



Porous Lead Plate Magnified Forty Times.



Lead-antimony With the Eutectic Alloy in Place.



Simple Apparatus for Expelling the Eutectic Alloy.

Conversely, on heating a solidified plate, the canals are found first to melt, and this fact has been utilized by Prof. H. I. Hannover, of the Copenhagen Technical High School, for the production of *porous metals*, which can be employed for example for the preparation of accumulator plates of surprising capacity.

If the canals are melted by reheating a solidified plate, a porous lead or antimony plate (according as there is an excess of one metal or the other) must in fact be obtained on expelling their molten contents. The question is only how this can be effected. The first of quite a number of different arrangements designed by Prof. Hannover, consisted of a gas pipe filled with mineral oil and closed at one end, the other end being connected to a fitting in which the plate is encased. (Sketch.) On heating the gas pipe the expanding oil drives the liquid metal out of the plate.

Even better results were obtained by a centrifugal arrangement for expelling the molten contents of the canals. The plates were inserted in molds fixed to a rapidly rotating axis, and provided with wire gauze windows through which the molten metal could escape. On account, however, of the minute fissures produced by centrifugal action, a special device had to be provided for tightening the plates during the process. Promising results have also been obtained with a vibratory arrangement for shaking the molten metal out of the lead plate. The porosity of the plates can be varied by altering the composition of the original alloy, the temperature of reheating, the speed of rotation of the centrifugal machine, etc. Thus, for instance,

the higher a lead-antimony plate is heated the more lead will the molten eutectic alloy dissolve.

Exhaustive tests of accumulator plates made from such porous metal, conducted at the central workshops of the Danish State Railway, have shown the new type of plate to give very great capacities.

Whereas the means so far employed for increasing the surface of accumulator plates (perforations and ribs) at most give a surface 8 times as large as the natural surface, Prof. Hannover has been able by his process to increase the natural surface about 130-fold, the number of hollows being 20 per millimeter. The drops of metal expelled during the manufacture of porous plates are at first invisibly small and only increase gradually by uniting with one another. The process allows millions of minute holes to be obtained in a few minutes which, on account both of their smallness and large numbers, it would be impossible to drill.

As regards further applications of porous metals there are doubtless many possibilities. They could, for instance, be used for filtering; as bearing-metal, the oil being fed through the pores; for plugs in conduits containing explosive gases, as catalyzers for chemical reactions, etc.

A Review of the Physics of Light—II*

Prof. Silvanus P. Thompson's Presidential Address at the Recent Optical Convention in London

Continued from SUPPLEMENT, August 24, 1912, page 115

NEWTON AND HUYGENS.

For more than two centuries the names of Newton and Huygens have been pre-eminent. These two men tower above their contemporaries and followers, dominant figures even to-day. The influence of Newton in science has been immense. His great genius, shown in his "Opticks," in the unraveling of the puzzle of the colors of the prismatic spectrum, and in his "Principia," in laying the foundation once for all of the laws of motion and of the doctrine of universal gravitation, won for him an almost idolatrous regard. We may recall Alexander Pope's couplet:

"Nature and Nature's laws lay hid in night;
God said, 'Let Newton be,' and all was light."

Even his mistakes—and they were few—were accepted as dogmas, as when he pronounced the dispersive power of prisms of different kinds of glass to be proportional to their refractive power, involving the impossibility of ever obtaining an achromatic lens. Even after a hundred years the Newtonians out-Newtoned Newton in their antipathy to anything that seemed counter to his views; and their hostility to Thomas Young's doctrine of interference is a matter of history. It is patent to anyone who will read the queries at the end of Newton's "Opticks" (1704) that while he held to the emission theory of light, he was quite alive to the probability that emission was performed in shining bodies by the vibrating motions of their parts (query 8); and he was prepared to admit that the several sorts of rays of different colors make vibrations "of several bignesses . . . much after the manner that the vibrations of the air, according to their several bignesses, excite sensations of several sounds" (query 13). Newton, "who looked all Nature through," who "surpassed the human race in power of intellect," who refused to frame hypotheses, must not be judged by the indiscretions or bigotries of his school. If we would appreciate his greatness, we must go back to his own writings, and see how he worked. If, following the modern views of Lord Rayleigh and of Arthur Schuster, we now have to admit that periodicities characteristic of the several rays are in reality imposed by the prism, and are not antecedently present in the white light, that does not derogate from Newton's achievement. The mathematical arguments which lead logically to the view that the prism manufactures the colors from the white light, and does not merely sort them out, seem unanswerable; but to some of us those arguments seem to be of that class which compel assent rather than satisfy the mind.

Christian Hugyens, Newton's great contemporary, propounded his wave theory of light in 1678, though his famous "Traité de la Lumière" appeared only in 1690. Few British students have ever read that rare work; but none can read it without being impressed with the genius of its author. Everyone knows of Huygens as the inventor of the wave theory of light; but how few are familiar with the contents of the treatise! He expounds the analogy of the propagation of light with that of sound, then points out the essential differences, and develops the geometrical notion of movements spreading in spherical waves. He had, in fact, to take into account six fundamental facts: (1) The rectilinear propagation of light; (2) the mutual penetrability of two beams where they cross one another; (3) the law of reflection; (4) the law of refraction (which he had learned from Des Cartes); (4) atmospheric refraction; (5) the finite speed of light, discovered by Roemer in 1676; and (6) the double-refraction of Iceland spar, discovered by Bartholinus in 1669. The insight with which, by aid of his conception of elementary waves building up an enveloping wave-front, he succeeded in giving a consistent theory, is a matter for wonder and admiration. He availed himself of Fermat's principle of least time, deduced from it the law of sines for refraction, and based on it the geometrical construction for his wave-fronts which now appears in all books on physical optics. It is true that he had no conception of transversality in the movements of his waves, or of the principle of interference, or even of the existence of trains of waves or of wave-length. His wave theory was far from being the complete doctrine of Young and Fresnel, and belongs to geometrical rather than to physical optics. But the exquisite skill with which he unraveled the intricacies of double refraction in crystals, and the anomalies of atmospheric refraction, must excite the admiration of every reader. His speculations as to the ether of space, his suggestive views of the structure of crystalline bodies, and his explanation of opacity, slight as they are, surprise one by their seeming modernness. He detected the double refraction of quartz, and discovered the phenomenon of polarization, while frankly unable to explain it. Another section of his book deals with aspherical forms of lenses for focusing light when one surface is prescribed.

That the "Treatise of Huygens" should never have been translated into English† is strange; perhaps it is due to the mistaken zeal with which everything that seemed at variance with the teachings of Newton was denounced. Now, after more than two centuries, it has seemed to me that the time has come to make reparation. Accordingly, an English version of the "Treatise on Light" has been published by Messrs. Macmillan in time to lay it before the present Convention.

Huygens was in many respects a notable personage. A Dutch aristocrat, a friend in his youth of Des Cartes, he built with his own hands in 1655 the telescope with which he discovered the ring of Saturn and the fourth of his satellites. He himself ground and polished glass lenses as did his famous compatriot Spinoza. In 1663 he was elected a Fellow of the Royal Society at the second meeting after the granting of the charter. The Royal Society possesses three telescope objectives ground and polished by him, one having 122 feet focal length, presented in 1691 by himself; two others of 170 feet and 210 feet focal length, the former presented by Sir Isaac Newton. In 1666 Huygens was called to Paris by Louis XIV., to aid in the formation of the Académie des Sciences. There he resided till 1678, and there he wrote the famous "Traité de la Lumière." He was again in England in 1689, for his brother records that on July 10th in that year he went with him in company with Newton to wait on King William III. for the purpose of recommending Newton for the vacant mastership of one of the colleges in Cambridge.

HUYGENS'S REJOINDER.

It has been objected, and by no lesser an authority than Sir George Stokes (Burnett Lectures on Light, vol. i., page 19), that Huygens's "grand attempt" to explain the rectilinear propagation of light by the superposition of undulations failed. "Notwithstanding all that Huygens has done, the existence of rays and shadows, one of the most obvious properties of light, had received no satisfactory explanation on the theory of undulations such as it came from the hands of Huygens." "This principle does not by itself alone suffice for the explanation of rays. It proves, or at least appears to prove, too much. It is as applicable to sound as, on the supposition that light consists in undulations, it is to light; and if Huygens's explanation of rays were complete, there ought equally to be rays of sound, and sound ought to present the same sharp shadows as light." Newton, in fact, had made the same objection in his "Principia" (Book II., Proposition XLII., and Scholium to Proposition L.), where he notes how sound spreads round obstacles, and that light travels as in rays. We know now that sounds can cast shadows if the wave length is small compared with the size of obstacles. We also know, and partly from the experiments of Newton on "inflexion," though he understood it not, that light can spread to a small extent into the shadows of objects, the sharpness of the shadow resulting from the minuteness of the wave lengths. But Sir George Stokes, in repeating Newton's objection, does not seem to have been aware that Huygens had himself answered Newton. This answer is not given in the "Traité de la Lumière," but in the "Discours de la Cause de la Pesanteur," which was printed in 1690, along with the "Traité de la Lumière." As the passage is not generally known, and as the discourse on weight has never been translated into English, I here supply a version of it from the original.

"He (Newton) will perhaps say to me that when one shall have granted me that for the transmission of light the ethereal matter consists in particles which touch one another, one will not see how light would observe the rule of being transmitted only in a straight line, as it is; because this is contrary to his Proposition 42 of Book 2, which says that the movement which spreads in a material fluid, after having passed through some aperture, is not propagated only straight from its origin, but that it diverges also laterally. To which I reply in advance that what I have alleged, in order to prove that light (save in reflection or in refraction) is propagated directly only, does not cease to be valid notwithstanding the said proposition. For I do not deny that when the sun shines through a window he does not transmit movement aside of the space illuminated; but I say that these deviating waves are too feeble to produce light. And though he will have it that the emission of sound proves that these lateral divergencies are perceptible, I hold for certain that it rather proves the contrary. Because if sound, having passed through an aperture, spread also laterally, as Mr. Newton will have it, the equality of the angles of incidence and reflection would not be so exactly observed as they are in an echo; in such a way that when one is placed in a spot whence no perpendicular can be drawn to the reflecting plane of a somewhat distant wall, one hears no echo whatever to the sound that one makes at that spot, as I have very often found experimentally. I do not doubt also that the experience which he adduces of the sound which is heard, notwithstanding an interposed house, would be found quite different provided that house were placed in the middle of some large lake, or so that there should be round about it nothing which could send back by reflection any part of the sound.

"And as for what he says that in some place, being in a room the window of which is open, one then hears the sound from outside, not by reflection from the walls but coming directly from the window; one sees how easily one may be deceived because of the multitude of repeated reflections which occurs as in an instant, in such wise that the sound which is heard as if coming immediately from the open window, may come from thence, or from places quite near, after a double reflection. I confess, then, so far as regards the undulations or circles which are formed on the surface of water, that things occur almost exactly as Mr. Newton declares; that is to say, that a wave, after having passed the aperture, spreads successively at both sides and always more feebly there than in the middle. But as for sound, I say that these lateral emanations are almost insensible to the ear; and so far as concerns light, they produce no effect at all on the eyes.

"I have thought that I ought to meet in advance these objections which the book of Mr. Newton might suggest, knowing the high esteem accorded, and rightly so, to that work; because there is none known more learned in these matters, nor any attesting a greater penetration of mind." ("Discours de la Pesanteur," pages 163 to 165.)

ABERRATIONS.

The enormous focal lengths were adopted by Huygens for his telescopic object glasses because of their comparative freedom from aberrations. No actual lens ever gives perfect stigmatic results; and every beginner knows that aberrations are of two classes—those that arise from the polychromatic nature of light, and those which, even when monochromatic light is used, are due to the form of the surface of the lens, and are often, though not very happily, termed "spherical aberra-

* Delivered June 19th, 1912.

† I do not forget the fragment translated by Prof. Henry Crew in the collection on the wave theory, published in New York in 1899. Here, however, the most interesting chapters on Atmospheric Refraction and Double Refraction are omitted.

tions." Newton calculated ("Opticks," pages 84 and 89) that in a 100-foot telescope with suitable aperture the aberration of color would be at least 1,200 times as great as the aberration caused by the sphericity of figure of the object glass. We know, in fact, that in despair at making a lens devoid of chromatic aberrations, he gave up refractors, and invented his reflecting telescope. But when, in 1757, Dollond, by the invention of the achromatic lens, removed the worst of the abberations, the correction of the aberrations due to form became the next desirable step. Des Cartes, Deschales, and other writers suggested various devices for grinding lenses with hyperbolic, elliptical, and other aspherical curves; but practical difficulties prevented their use. In the early part of the nineteenth century Coddington and Airy, the younger Herschel, and others investigated in great detail the aberrations of lens combinations, and brought that part of optics to a high pitch, though much of their work remained unknown outside England. The complexity of the problem of the passage of a ray or pencil through a centered system of spherical lenses has been alluded to already. The complexity arises entirely from the trouble occasioned in continually being obliged to shift the origin from which the angular position of the ray is measured, from one point to another, as the ray passes from one refracting surface to the next. Lagrange solved the detailed problem by the use of continued fractions. Trigonometrical formulæ for the purpose were greatly used by Steinheil, and improved by von Seidel. Von Seidel, in 1855, introduced a different method of considering the successive deviations, leading him to define five conditions, each expressed in terms of the sum of a series, which must be severally fulfilled if the performance of the optical system was to be stigmatic and collinear. The conditions were that each sum must be severally zero. In this way the three errors of central aberration, coma, and radial astigmatism, and the defects of curvature and distortion, could be successively predetermined in a given lens combination. Abbe introduced another method of dealing with aberrations by the use of the "optical invariant," used throughout in Czapski's Hand Book. Earlier in time is the Hamiltonian method of treating the same complex problems by use of a "characteristic function," a development of Fermat's method of least time. Though of great generality, this has been little used. Thiesen and Chalmers have sought to modify it. Recently, Schwartzschild has restated Hamilton's function in terms of the variables used by von Seidel, yielding complete formulæ suitable for calculating lenses, while Lord Rayleigh, in the fifth volume of his "Scientific Papers," the publication of which is one of the milestones in progress, has shown how readily the number and nature of the five constants are deducible from Hamilton's principle. Of the five equations of condition yielded by von Seidel's method, great stress is justly laid on the second (the condition for the removal of coma), which is equivalent to the sine condition independently discovered by Abbe. Abbe afterward found that this condition had been well fulfilled in the famous heliometer objective of Fraunhofer, and, still more remarkable, that it had been approximately fulfilled by the makers of almost every[10] good wide-angled microscope objective, by means of empirical corrections, since the law was unknown to them. "They builded better than they knew." The other four conditions of von Seidel had all been previously worked out on other plans by Airy or Coddington. The recent admirable tract on the "Theory of Optical Instruments," by Prof. E. T. Whittaker, published in 1907, discusses von Seidel's five conditions, with a convenient notation; and using Abbe's invariants, R. A. Herman[11] and R. A. Sampson[12] have also contributed to the detailed study of aberrations; the latest contribution being that of H. C. Pocklington,[13] who has modified Lord Rayleigh's method to obtain expressions suited for the detailed calculation of particular systems. Two important contributions to the study of aberrations come from Scandinavian investigators, Charlier and Gullstrand, the latter of whom, in 1900, published an elaborate monograph dealing both with astigmatic and non-astigmatic pencils. Nor must it be forgotten how in 1905 C. V. Drysdale showed how the curvature method of geometrical optics can be extended to certain of the aberrations. In 1906 appeared an important work by Mr. H. Dennis Taylor, "A System of Applied Optics," which is of the more interest because written by a most accomplished practical optician and instrument designer. In it there is worked out, chiefly on the basis laid down by Airy and Coddington, a complete system of formulæ for lens systems, the value of which is enhanced by the addition of many examples of their practical application; but the value of the work is reduced by the adoption of a method of reckoning signs that is awkward, though consistent with itself.

Comment was made above that the complexity of all the formulæ for computing the path of a ray through an optical system arises from the necessity of carrying on the calculations from one surface to another by a series of transferences. Now the analytical or arithmetical complications involved in these transferences could be dealt with, as remarked by Larmor, quite simply by graphical methods, if only those methods were capable of the necessary precision. But where small angles are involved graphic processes are exceedingly rough, hence the preference for analytical processes. This suggests the thought that some adaptation of vector calculus and the use of complex numbers, which in recent years has yielded excellent results in electrical problems as a substitute for clumsy graphic processes, might reasonably be expected to produce equally good results as applied to optics. A new optical calculus of this sort might require the tabulation of new functions, but assuredly is worthy of being formulated; and if carried out in conjunction with the method of convergencies, that is, upon the unit of converging the dioptric, which has been in vogue in British teaching for nearly a quarter of a century, would prove still more valuable. There is abundant room here for younger workers to strike out a new departure.

[10] Abbe, "Sitzber. Jenaischen Gesellschaft für Medecin und Naturwissenschaft," 1879.

[11] A Treatise on Geometrical Optics. Cambridge, 1900.

[12] "Proc. Lond. Math. Soc.," vol. xxiv., page 33, 1898.

[13] "The Aberrations of a Symmetrical Optical Instrument." Proc. Roy. Soc., November, 1909, Series A, vol. lxxxiii., pages 99-106.

ILLUMINATION.

One branch of geometrical optics has not been touched upon—that of illumination, involving questions of the distribution of light and the measurement of it in quantity and intensity by photometers. During the past seven years there has been great activity in the development of this branch, and new societies have grown up for its study. Of this subject the best view will be obtained by the perusual of the masterly book entitled "Illumination" (published in 1911), by Mr. A. P. Trotter, himself a pioneer in two directions—the photometric measurement of the amount of illumination which is received upon any surface, whether roadway, table, or wall; and the redistribution of the light emitted by any luminous source (whether gas or electricity) by means of dioptric globes or shades. Though a better standard source of light than either the Harcourt pentane lamp or the Hefner amyl-acetate lamp is still a desideratum, it is satisfactory to know that international agreement upon the unit of light is practically secured, through the collaboration of the four great laboratories at Sèvres, Charlottenburg, Bushy, and Washington. Committees have been actively at work on the questions of minimum illumination required in schools, libraries, factories of various kinds, and in roads and streets. Even the House of Commons has awakened to the fact that the illumination enjoyed by its members is only about half a candle-foot, whereas for comfortable reading it should be two or three times that amount. Photometry has, indeed, grown since the photometry law of inverse squares was first announced by Deschales in 1674, or since the early treatises of Bouguer and Lambert. New forms of photometer have multiplied, and every month sees fresh developments. Among the novelties in distributing appliances is the simple and beautiful device of Messrs. Mackinney and Chalmers for the uniform illumination of pictures in such a way that from no standpoint can any reflected view of the lamp be seen.

To be continued.

The Cost of a Superfluous Language

THE Belgian government, according to the *Moniteur Industriel*, uses both the French and the Flemish languages for all official documents it issues. All the Parliamentary documents and official publications are published in the two languages. In the Flemish districts, i. e., Flanders, the Antwerp and Limburg provinces, and North Brabant, several of the district boards use Flemish exclusively; others use the two languages; still others use French alone. In the Walloon districts French is the only language. Speaking generally, however, French is the language exclusively used throughout Belgium. Flemish is, as a rule, considered by the population as the common idiom, spoken only by the totally or partly illiterate members of Belgian society. The existence of the two languages means an increase in expenditure. The official publications in Flemish have no subscribers and also no readers; their issue is continued "owing to the platonic respect of a principle," as stated by our contemporary. They are printed, and are then sent to the pulping-machine for utilizing afresh the paper upon which they have been printed. The Flemish as now used is a kind of dialect dating back to the fifteenth century, which everybody has long ceased to try to understand. Dutch is considered the literary language of the Flemish race. The Dutch government once asked the Belgian Ministry of Agriculture for the communication of a number of special documents; the Flemish edition was sent to Holland, but the Dutch authorities returned these, asking for the French edition, which, they stated, "they were much better able to understand." The Belgian Railway Ministry published some time ago two time-tables, one in French and the other in Flemish; the first found a ready sale, the other went to the pulping-machine. Then one single time-table was printed in the two languages, but this was most badly received by the public, owing to its complexity and the difficulty encountered in using it. Thereupon a private company printed a time-table in French only; this has now entirely superseded the Government time-table. In fact, the Ministry of Railways publish every year four editions of their time-table, in the two languages, the sole use of which is to enable a private company to get out its own, which is the only one finding a ready sale. The various government departments publish frequently specifications in the two languages; these specifications contain a large number of technical terms which are now in current use in French, but have no equivalent in Flemish. New Flemish words are coined by the translators, and the coining of new words has to be carried on to such an extent that the Flemish readers are at a loss to understand the specifications. The Flemish specifications are nevertheless printed, and shortly after they are destroyed in bulk. It is interesting to add that the Antwerp Municipality hold the whole of their discussions in French; in Antwerp French is also the language used at the Exchange and for all general business intercourse. But, nevertheless, the publications issued by the Municipality dealing with the working of the port are exclusively issued in Flemish, making it incumbent upon the shipping agents themselves to prepare translations for their companies.

The Royal Institute of Public Health.

THE Congress of the Royal Institute of Public Health opened yesterday in Berlin, under the presidency of Earl Beauchamp. The Congress sits for four days, and has been favored with the use for its meetings of the Prussian Upper House. A number of German and other foreign authorities are taking part in the proceedings The congress is divided into five sections, over one of which, devoted to Municipal Engineering, Architecture, and Town-planning, Mr. P. C. Cowan, D.Sc., M. Inst. C.E., is presiding. Mr. Cowan, in his presidential address, referred to the hygienic formula enunciated by Hippocrates over 2,000 years ago—"pure air, pure water, and a pure soil"—as still embodying the ideal principles for sanitarians. Later knowledge had not widened these requirements, but had shown how they might be fulfilled. Placing scavenging first among the duties of town authorities, Mr. Cowan drew attention to various advantages of thoroughness and promptness in this particular branch of the public service. He also deprecated the practice of the dry sweeping of streets as often worse than useless. With regard to water supply, it was pointed out that in America large quantities of water of questionable quality were supplied in town, whereas in the British Islands less was used, but it was of a better standard. It was obviously safer to use a smaller quantity of really good water than a large supply which was none too pure. In Great Britain and Ireland catchment areas of ten to seventy square miles had been secured by twelve cities. The advantages of purity in supply were illustrated by the fact that in Berlin, Copenhagen, Edinburgh, Hamburg, London, Paris, and Rotterdam the typhoid death rate in recent years had been below ten per one hundred thousand. With regard to the treatment of water, mechanical filters were being more extensively employed, though the sand gravitation filter was still the most common. The latter filters should be used in rotation with the beds in series, whereby the disturbance due to cleaning was considerably postponed, and filters could be allowed to ripen after cleaning with less inconvenience. Sterilization by ultra-violet rays appeared to be successful in the case of clear waters. In the case of a turbid supply such treatment might be applied after filtration. It was essential that the water supply should be under constant expert supervision. With regard to drainage, Mr. Cowan considered that the intercepting trap commonly placed on house drains before they joined the sewers could only safely be dispensed with when the standards of plumbing and house drainage, etc., have reached a much more advanced state than is yet general in the country. With regard to sewage disposal, Berlin had sewage farms aggregating seventy square miles in extent. The profit on the working of the farms was said to be 11s. per million gallons; but including capital charges, the net cost was about 6l. per million gallons. After dealing with gas supply and motor transport, housing of working classes was touched upon.—*Engineering*.

The Centenary of the Krupp Wor

By Dr. A Graden

THE foundation of the firm of Krupp as a steel foundry in Essen on the Ruhr coincides with the memorable period of 1811-1812. Preparatory steps had been taken toward the end of 1811 when Friedrich Krupp, a merchant of Essen, established the firm of Friedrich Krupp with a view to installing "Works for Manufacturing English Cast Steel and all Products resulting therefrom." At the same time he acquired in the north of the town a small water power on the river Berne where he expected to build the new factory.

Only a short time beforehand, Krupp had made the acquaintance of two retired officers, two brothers of the name of Kechel von Kechlau who described themselves as "Steel Manufacturers" and who succeeded in convincing him that they possessed the much sought-after flux on which the manufacture of cast steel was thought to depend. These two brothers pledged themselves to instruct Krupp in the technicalities of cast steel manufacture and who guaranteed a profit of 40 to 50 per cent on the capital invested. As, however, the melting tests carried out in conjunction with the Kechlaus failed to give any practical results, Friedrich Krupp in 1814 severed his connection with these would-be inventors and ventured on steel manufacture without any outside assistance. However, all his endeavors never met with any real success, and he consumed health and fortune in a useless struggle against adverse circumstances. When Friedrich Krupp died in 1826 at the age of 40 years, he left to his 14-year old son Alfred little more than the secret of cast steel manufacture. Alfred Krupp (1812-1887) thus had to pass in his turn through the school of hardship and untiring work, and even a modest share of success was slow in coming. When in 1848, i. e., 36 years after their foundation, he became sole proprietor of the works, these were of rather limited dimensions and only employed 70 hands. The advent of railways, however, gave rise to more prosperous developments, and a lucky invention in the field of the peaceful industries, viz., the manufacture of welded seamless railway tyres, supplied the means for carrying out the lengthy experiments on the use of cast steel in gun manufacture. The works now developed into a gun factory and by wonderfully rapid strides assumed an enormous importance for military armaments and incidentally for the industrial and political future of Germany. The Krupp works even anticipated political developments and had long become a great industrial power when the German Empire, with the help of Krupp guns, came into being. This anticipation of events is particularly noticeable in appreciating the valuable help German industry received from Krupp on first venturing upon the markets of the world.

The Krupp firm has, however, been a pioneer also in another line, viz., in the field of social work, in connection with the wonderful provisions made for the well-being and future of their men. Sick Funds, Pension Funds, providing for illness, accidents, disablement, old age and death, were founded as early as the fifties of last century, and when the German Workman's Insurance started, the excellent institutions created by Alfred Krupp served as models.

This vast industrial organization was taken over by his son Friedrich Alfred Krupp (1854-1902) who, actuated by the same spirit as his father, extended its limits and improved its technical and financial organization.

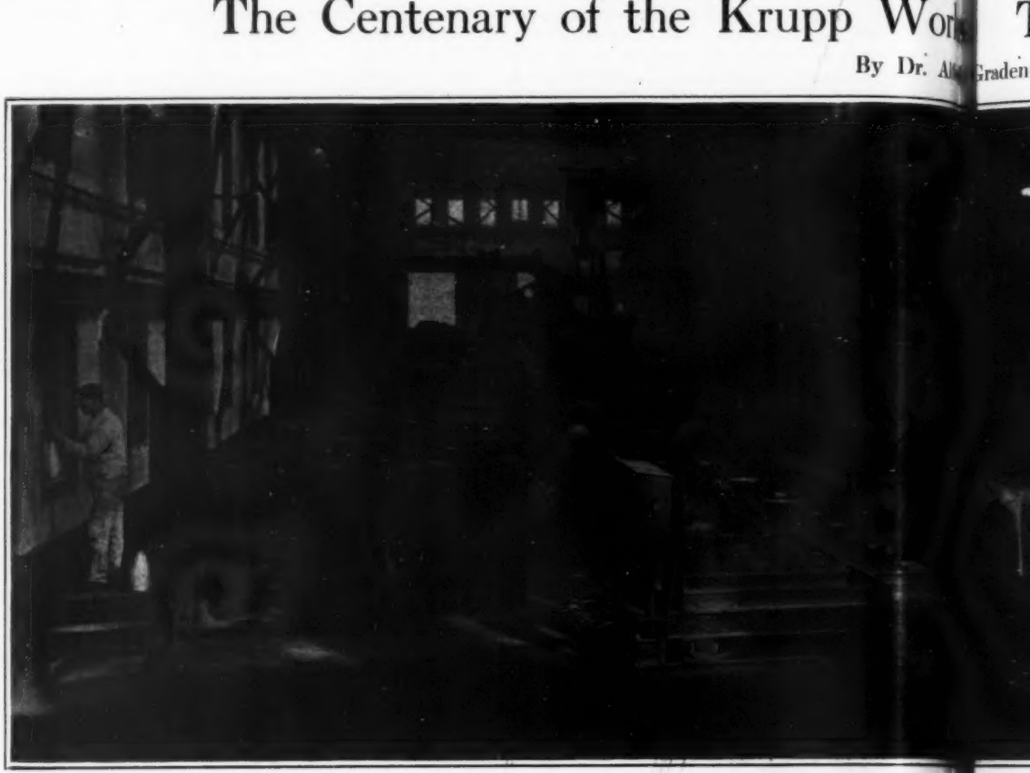
Now, on entering the second century of its existence, the Krupp factory is in the hands of the fourth generation, which faithfully adheres to the family traditions and is steadily advancing the standing of the firm. The Krupp factory has of course long outgrown the limits of a simple steel foundry and at the present day constitutes one of the largest industrial organizations in the world. In order to give an approximate idea of its importance, a list of the principal works and factories belonging to Messrs. Krupp will be given in the following:

There is first the old steel foundry at Essen, with proving grounds at Meppen, Tangerhutte and Essen. This is fed from the firm's own coal mines at Essen and Hordel (near Borchum), a number of iron mines in Germany, part of the iron mines of Bilbao (North Spain), and from some Rhenanian steel and iron works managed by the firm. Special wharves have been installed at Rotterdam for the transport of ores on the firm's own ore steamers.

Apart from the Essen firm with its many annexes, the following branches should be mentioned:

1. The Friedrich Alfred Steel Works at Rheinhausen-Friemersheim. 2. The Annen Steel Works at Annen, Westphalia. 3. The Gruson Works at Magdeburg-Buckau. 4. The Germania Ship Yards—one of the most important firms of German ship builders—at Kiel-Gaarden.

The total number of hands employed at the Krupp Works on June 1st, 1912, worked out at 71,221. Of this enormous total 38,264 corresponds to the Essen Steel Foundry and the proving grounds, 9,849 to the coal mines, 4,410 to the iron mines, 905 to the Rhenanian Iron Works, 55 to the Rotterdam Wharves, 6,587 to the Friedrich Alfred Steel Works, 1,019 to the Annen Steel



The Siemens-Martin S of the

The Great Gu Krupp W

The Rise of a Great Steel Plant

Dr. Alfred Gradenwitz

Martin Steel Plant of the Krupp Works.

Great Gun Krupp Works.

Works, 4,700 to the Gruson Works, 5,432 to the Germania Ship Yards.

The following are some of the important products of the Essen works: Crucible steel, electro steel, Siemens-Martin steel, Bessemer steel, steel alloys such as chromium steel, nickel steel, chromium-nickel steel, etc., special steel as used for automobile construction, hard steel, cast iron objects, wrought iron and bronze. Of military materials should be mentioned guns with their full equipment and ammunition, rifle barrels and armor in the form of rolled plates or sheets as well as cast steel. The Essen works further manufacture all sorts of railway, ship-building and engine-building material, etc. The Rhenanian Iron Works mainly turn out pig iron, engine castings, cast iron boilers, vessels for the chemical industry, fly-wheels, pulleys, etc. The Friedrich Alfred Iron Works, apart from pig iron and raw steel, manufacture all sorts of rolling-mill products for railway and bridge building, etc., and the Annen Steel Works, cast steel parts for ship, locomotive, turbine and general engine construction, as well as rifle steel. The Gruson Works manufacture cast iron and steel, e. g., chill castings and malleable cast iron, military materials such as armor, smaller guns, gun carriages, limbers, ammunition and industrial products of every description (molded and wrought iron and steel, machine parts, complete machines, crushing and dressing plants, cement mills, salt and oil mills, machinery for linoleum and rubber factories, colonial machinery, rolling mills, squeezers, complete equipments for metallurgical works and for cable factories, cranes, installations for the loading of bulk goods, tipping wagons, etc.). The Germania ship yards finally build warships, rapid steamers, passenger and freight steamers of every description, floating docks, and the like, ship engines, stationary engines, turbines, oil motors, condensers, water-tube boilers, etc.

The following statistical data will likewise be of interest: The Krupp Works comprise three blast-furnace plants with a total of 16 blast furnaces, turning out 3,900 tons every 24 hours, as well as 1 pit furnace, 5 coking plants containing 580 coking furnaces with an output of 3,180 tons per 24 hours; 11 converters with a total capacity of 157.5 tons; 55 Martin furnaces with a capacity of 1,340 tons; 24 crucible furnaces for steel manufacture, 30 crucible furnaces for bronze and brass castings and 12 crucible furnaces for malleable castings; 37 cupola furnaces with a total daily output of 2,600 tons; 3 electric melting furnaces with a total capacity of 32 tons; 5 flame furnaces; 349 heating furnaces; 234 shot furnaces; 29 kilns (for dolomite, clay, stone, bricks, etc.). The dressing plants have a daily output of about 5,300 crucibles, 231,483 pounds of steel moldings, 198,414 pounds cast iron moldings, 35,314 cubic feet of flux, 734,132 pounds of fireproof materials, and 229,278 pounds of briquettes. There are 657 stationary and 180 transportable steam boilers with a total heating area of 724,417 square feet, as well as 24 gas generators producing 2,296,700 cubic feet of power gas and 151,934,000 cubic feet of heating gas in 24 hours.

The electrical power and lighting plants comprise 34 engine houses, 10 converter stations and 42 transformer stations, feeding about 5,000 electro-motors, 5,500 arc lamps and 65,500 incandescent lamps. The telegraph system comprises 29 stations, 39 Morse apparatus and 77.6 miles of telegraph lines. The iron mines comprise 33 separate plants of an aggregate output (in 1911) of 1,143,000 tons and the coal mines 11 pits with an aggregate output of about 2,600,000 tons.

In the course of the ordinary service no less than 167,000 chemical analyses and 319,000 resistance tests were made. The consumption of the works in 1911 was:

Pig Iron	882,000 tons
Coal	1,390,000 "
Coke	1,288,000 "
Briquettes	10,198 "
Ore	2,318,000 "
Fluxes	496,000 "
Water	54,618,000 "
Electric Current	107,225,000 kilowatts

The Water Works have an output of 1,943,330,000 cubic feet and comprised 323.7 miles of conduits. There were no less than 1,279 prime movers generating a total of 250,000 horse-power, 11,314 machine tools and 5,089 electro-motors of a total of about 107,000 horse-power.

The Hammer Works, rolling mills and squeezers comprise a total of 199 steam hammers, 35 shaft-driven hammers, 160 hydraulic presses with a total capacity of 70,000 tons, 1,875 compressed air tools and 26 rolling mills for rails, girders, plates, bars, etc.

The 2,075 lifting, transporting and loading devices of 33 to 330,000 pounds individual capacity have a total output of about 41,900,000 pounds.

The works also comprise comprehensive railway systems with a total length of track amounting to 199.6 miles, 106 locomotives, 4,452 carriages, 7 steamers with a total capacity of about 5,500 tons and an extensive telephone plant with a total length of line of 795.2 miles, and 1,431 apparatus on which about 19,000 conversations are held every day.

The Uses of Acetylene*

A Review of Twenty Years' Progress

By Prof. Vivian B. Lewes

It is now 20 years since, in May, 1892, the Canadian engineer, Thomas L. Willson, made carbide of calcium in an electric furnace, and in September of that year sent samples of it to Lord Kelvin, while in the same year Henri Moissan independently discovered how to make this remarkable compound, and on December 12th, 1892, published his discovery in a paper read before the French Academy. No sooner had it become possible to manufacture carbide of calcium in quantity than acetylene gas, which up to that date had been made only in small volumes by laborious processes, but which could be produced with the greatest ease by the action of water on the carbide of calcium, began to assert its claim to be recognized as a source of light, and by 1896 it was established as a valuable illuminating agent. Since that date it has grown steadily in popularity for the lighting of country houses and other buildings in isolated positions, where the absence of a coal gas supply or electricity has rendered the installation of a private lighting plant the only means of escape from the glimmer of candles and oil lamps. Abroad the use of acetylene as an illuminant has increased much more rapidly than in this country, especially for the lighting of small towns and villages, but still England can show a six-fold increase in the last ten years if advance be measured by the sale of carbide of calcium. It must be remembered, however, that of late years the uses of acetylene have developed largely in directions apart from lighting, and that fact probably accounts for much of the increased consumption.

MANUFACTURE OF CARBIDE.

In tracing the advances made during the first 20 years of the acetylene industry the manufacture of carbide of calcium claims attention first. In Willson's plant at Spray the base of the furnace consisted of a heavy iron plate on which rested two thick slabs of carbon, the carbon in connection with the iron base forming the lower electrode, while the upper electrode was a heavy carbon block 12 inches by 8 inches in cross section and 3 feet long. The arc was struck between the two, and a mixture of lime and coke, pulverized finely enough to pass through a 20-mesh sieve, was fed in between them. The lime at the temperature of the arc, which was between 3,000 and 4,000 deg. Cent., fused and acted as a flux to the carbon, which reduced the lime, forming the metal calcium with evolution of carbon monoxide, and the calcium then reacting upon the excess of carbon present produced the carbide of calcium. As this action took place the upper electrode was gradually raised, and the formation of the material continued on the surface of the growing mass, thus slowly building up an ingot which consisted of a core of crystalline carbide with a crust of semi-converted material. This method of making the carbide was called the "ingot" process, and is still the one chiefly employed in America, although instead of being carried out in a stationary furnace, as was done in the early days, a rotary furnace of the type first introduced by Bradley and Horry is employed, in which the slow revolution of the furnace removes the ingot as it is formed from the arc and brings a fresh portion of the charge under its action.

On the Continent, however, the ingot process has been superseded by the use of a furnace in which the mixture is fed continuously between the carbon lining of the furnace, which acts as one electrode, and a square block of carbon smaller in dimensions, which forms the other electrode, the carbide remaining in the fused condition in the bed of the furnace, from which it is tapped as it accumulates. This process has the advantage of being easily worked, but its product, known as "run" carbide, often contains a lower percentage of true carbide than the ingot, because in order to ensure the liquefaction a slight excess of lime is used, and this remains in the finished product.

The drawback to the ingot process is a crust of imperfectly converted constituents, which gives a lower yield of acetylene than the true carbide. In preparing the product for the market the outer portion of this crust is therefore removed by a sand blast, but the richer portion of it is broken up and packed with the carbide. When the removal of the crust is carefully carried out the crystalline carbide of calcium obtained by the ingot process is the purest that can be got, and gives a gas yield, when acted on by water, of up to 5½ cubic feet per pound, the average yield of the "run" carbide being from 4.8 to 5 cubic feet.

The purity of the acetylene is governed entirely by the purity of the materials used in making the carbide. Accordingly the lime is made from the purest obtainable carbonate, specially burnt by gas, while the carbon is in the form of anthracite, coke, or charcoal. The last, though the purest of the three, has the disadvantage of lightness, which adds to the dust troubles found in the carbide factory. The ideal form of carbon, which, however, would be far too costly for practical use, would be what is known as "retort carbon." In the early days of the acetylene industry the composition of the carbide varied in purity as well as in gas-yielding power, the beautiful crystalline ingot carbide made by the water power at Foyers, in Scotland, giving over 5 cubic feet of acetylene of a high degree of purity per pound, while some of the run carbide, owing to its being kept too long at the temperature of the arc, would sometimes yield only 4 cubic feet and often contained phosphides which contaminated the acetylene with phosphuretted hydrogen, and caused a slight haze in rooms in which the acetylene was burnt. At the present day the carbide sold in this country by the leading firms is generally guaranteed to give 4.8 cubic feet of gas per pound, and contains only the smallest trace of deleterious impurities.

The main factor in obtaining a cheap supply of carbide of calcium is, of course, the power, so that the carbide industry has become localized near sources of cheap water power, and the selling price has been reduced to about 13 pounds 10 shillings per ton. The effect of cheap water power in localizing the industry is indicated by the following table, which gives the amount of carbide manufactured and the quantity used and exported for various countries in 1911:

	Made tons.	Used tons.	Exported tons.
Sweden and Norway.....	52,000	4,000	48,000
United States	50,000	37,000	13,000
France	32,000	31,500	500
Switzerland	30,000	4,000	26,000
Italy	28,000	23,000	5,000
Austria and Hungary ...	22,500	17,000	5,500
Canada	12,000	8,000	4,000
Spain	18,000	16,000	2,000
Germany	7,000	36,230	.....
England	2,000	16,000	.....
Other Countries	5,200	63,800	.....

From this it will be seen that in some countries the manufacture is far in excess of the amount used, with the result that an export trade is created, while other countries, among which Germany and England are the chief, use far more than they make, and are therefore dependent upon external supplies.

GENERATORS AND BURNERS.

As regards the generators in which, by decomposition with water, the carbide is caused to yield acetylene, the whole trend of the last 15 years has been in the direction of improving workmanship and material, and as far as possible simplifying the mechanical devices that form the essential feature of the various automatic machines which have been devised to generate the gas as required, so doing away with the space and initial cost of a gasholder. It is, moreover, a hopeful sign that the importance is now understood of having an installation fitted up by men skilled in this particular class of work, and while composition pipe with its attendant dangers and drawbacks is largely used on the continent, it has been realized in England that only the best iron barrel should be employed.

When acetylene was first introduced it was found impossible to burn it in ordinary union jet burners, as they did not give sufficient aeration to the gas, with the result that a heavy and smoky flame was produced. In America air was mixed in small proportion, with the acetylene before it reached the burner, but this was soon recognized to be a dangerous procedure, and it was shown that with the smallest-sized flat flame burner and sufficiently high pressure, magnificent illuminating results could be obtained. Even under these conditions smoking was noticed after a certain time, and when the steatite head of a smoking burner was cut in halves it was found to be carbonized for some distance into the mass. This suggested the theory that, as acetylene is polymerized by heat into liquids like benzine, the distortion of the flame and consequent smoking were brought about by the heat of the burner tip forming liquid products from the acetylene, which soaking into the steatite and becoming carbonized there led to further catalytic action and the growth of carbon filaments which distorted the flame. There have not been wanting observers, however, who have attributed this trouble to other causes, and MM. Granjon and Beaupré made experiments which led them to believe that traces of phosphoretted hydrogen in the gas were the active cause. It is undoubtedly true that the purer the acetylene the less frequently does smoking take place, and it is probable that both theories are to a certain extent correct.

This trouble with acetylene burners is now a thing of the past. All modern burners are so made as to suck in at the tip of the burner sufficient air to surround the escaping jet of gas with an air envelope, which prevents actual contact of the gas with the steatite tip, and, partly by reducing contact and partly by cooling the tip, prevents carbonization. The two jets from separate tips impinging upon each other play themselves out into a flat flame, and the rush of gas through the air draws in sufficient oxygen to give smokeless combustion with high illuminating power. The last step in perfecting the acetylene burner has been so to arrange the aerating power of the burner as to enable the flame to be turned low.

COMPRESSED AND DISSOLVED ACETYLENE.

So far as can be gathered from statistics, the yearly demand for acetylene for house lighting has now settled down to a very uniform level, but the gas has been gradually achieving popularity in other directions. In the early days of the industry it was found that it could be compressed, under much the same conditions as carbon dioxide, into a liquid, which could be stored in steel bottles and allowed to resume the gaseous condition when needed. But the investigation of several accidents which happened in the United States soon showed that in the compressed condition it was very explosive, and its use in the liquid state was prohibited.

Later, it was shown that certain liquids have the power of absorbing gaseous acetylene under pressure in very large quantities. It was pointed out by Claude and Hess that at 15 deg. Cent., independently of pressure, acetone would take up no less than 25 times its own volume of acetylene, and as the volume of the gas varies inversely as the pressure that is brought to bear upon it, the acetone will go on absorbing acetylene at the rate of 25 times its own volume for every atmosphere of pressure to which the gas and acetone are subjected. This fact suggested the idea that an acetone solution of acetylene under pressure might be used as an easy means of storing the gas; but it was found that the solution also was capable of explosion, and the further step was made by M. Janet of filling a strong steel cylinder with porous briquettes, and soaking them with a fixed percentage of acetone. Since this acetone will absorb about ten times the normal volume of the cylinder of acetylene for every atmosphere of pressure to which the gas is subjected, and as compression up to ten atmospheres—i. e., 150 pounds per square inch—is permitted, the cylinders contain at ten atmospheres' pressure a volume of gas equal to 100 times their cubic content. Experiments made on a large scale showed that under these conditions the dissolved gas is free from any danger of explosion.

VARIOUS APPLICATIONS.

The fact that cylinders capable of giving off a large volume of acetylene could be thus prepared had an enormous influence in advancing the use of the gas for lights of various kinds. Though in this country dissolved acetylene has not made great advances for railway lighting, it has been found excellent for this purpose elsewhere, owing to the smallness of the space required and the much longer period which elapses before the cylinder requires recharging. It has a wide field in the lighting of motor vehicles; a cylinder of convenient size is carried on the footboard, and by means of a proper reducing valve supplies the lamps without the troubles incidental to small generators. For buoy and coast lighting dissolved acetylene has many obvious advantages. The light has great brilliancy and penetrating power: with flashing lights a shorter light period can be employed than with most other illuminants, and flashes of short or long duration can be obtained by automatic means. The great storage capacity also of a small cylinder does away with the need of frequent recharging.

The high heat value of acetylene when burned with oxygen suggested at quite an early period that oxy-acetylene burners would be of great use to metal workers, and this has now proved to be one of its most important developments. It is very largely employed for autogenous welding of iron and steel, as both acetylene and oxygen can be obtained under pressure in cylin-

* Reproduced from the London Times.

ders, and the flame of the blow-pipe regulated so as to give a reducing instead of an oxidizing effect on the metal, the heat being steadily maintained and localized with great effect. For the repair of metal work in inaccessible positions it has proved itself of the greatest possible value, and for the repair of ship's boilers and boiler work it is used in many dockyards.

It seems probable that a great increase in the use of acetylene will take place during the next few years, owing to its adoption for self-starting devices for motor-cars, for which purpose it is very largely used in America. As nearly every motor-car carries acetylene headlights, supplied either from a cylinder of dissolved acetylene or from a small generator, the gas can be made readily available for an explosive mixture in the cylinders of the engine. In America several systems are in use. In some the mere pressing of a button or the turning of a valve on the dashboard allows the injection of a mixture of acetylene and air into the cylinders. In another the last few strokes of the engine before stopping draw a mixture of acetylene and air into the cylinders, and, acetylene being a permanent gas, the mixture is there ready for starting when needed. In other systems, again, the feeding of the acetylene into the cylinders is brought about by the pressure from the dissolved acetylene bottle. A high pressure is by no means an essential, and little or no objection can be taken to the low-pressure systems. As the dissolved acetylene that supplies the headlights has its pressure reduced to a few inches by the regulating valve, it is well adapted for use with self-starters, the wide range over which mixtures of acetylene and air are explosive rendering the attainment of an explosive mixture for this purpose in the engine cylinders comparatively easy. Another advantage of using dissolved acetylene, both for welding and for self-starters, is that the gas is obtained in a condition of purity, which is impossible with a small generator, but is a necessity for successful working.

The "Green Flash"

A Natural Phenomenon Illustrated by Artificial Means

On a clear calm day watch the sun sink below a distant and sharply defined horizon, such as the line parting the sea from the sky, or the crest of a far-off hill. At the instant the topmost segment of the solar disk is passing out of sight you may see something interesting. The color of the disk has been red or yellow; but the last visible bit of it suddenly turns bright emerald green, or possibly greenish blue. This phenomenon is called the "green flash."

In the *Jahrbuch der Astronomie und Geophysik* for 1910, Dr. A. Kühl states the two principal explanations of this phenomenon that have been offered, viz., (1) that it is an effect of dispersion, the green rays from the sun being more refrangible than the red, and disappearing later at sunset; and (2) that it is wholly subjective; the eye, fatigued by the reds and yellows of the spectrum, seeing an "after-image" of complementary hue the instant after the real object has disappeared.

Dr. Kühl prefers the latter explanation, and proposes the following experiment in support of it:

Fasten to a wall a sheet of pale blue paper, to represent the sky, and below, but overlapping this, a sheet of dark gray paper to represent the surface of the sea. Make cardboard disks of several colors—yellow, orange, vermilion, carmine—representing various appearances of the setting sun. Each of these must be provided with a handle, which may be introduced back of the "sea," so as to manipulate the setting of the "sun" behind the latter. These arrangements will be clear from the accompanying diagram. (Fig. 1.)

Now, trying one "sun" at a time, cause it to set with a slow and somewhat unsteady movement—imitating the quivering appearance due to varying refraction through a heterogeneous atmosphere. As the "sun" disappears, an after-image is seen, complementary in color to the paper disk. For a yellow disk it is blue; for an orange disk, blue-green; for a vermilion disk, a greener shade of blue; and for a carmine disk, a brilliant green. Carmine gives decidedly the best results.

This experiment "works" beautifully, and it is quite conceivable that the process which it illustrates may sometimes contribute to the production of the "green flash." It is not, however, the principal cause of the phenomenon. This will be at once apparent when it is stated that the flash has been frequently observed at *sunrise*, the green color appearing *before* the reddish or yellowish disk of the sun comes into view. In this case the physiological theory fails altogether; as the retina has had no chance to become fatigued by the red of the sun before the green color appears.

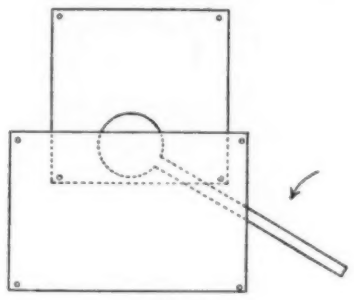


Fig. 1.

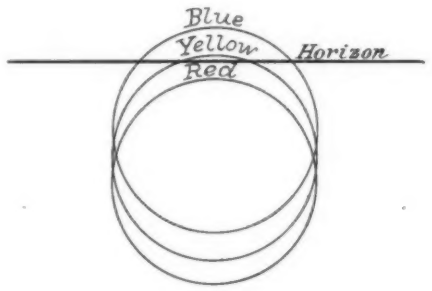


Fig. 2.

The principal explanation of the "green flash" is undoubtedly that given some years ago by Prof. Arthur Rambaut[1]; and as it is possibly not familiar to many readers of the SCIENTIFIC AMERICAN SUPPLEMENT, we venture to repeat it here.

The rays of the setting sun are refracted, in passing through the atmosphere, to such a degree that the sun has actually sunk completely below the horizon when it appears to us to be first in contact with it; that is to say, the solar image is apparently elevated by an amount about equal to its own diameter. The rays corresponding to the different colors of the spectrum are not, however, equally refracted; the red is the least refrangible, the other colors more so, in the order orange, yellow, green, blue, indigo, violet. Hence, as the upper limb of the sun passes out of sight, the colors disappear in this order. At sunrise, the colors appear in the reverse order. The violet and indigo fail to impress the eye for two reasons; (1) because the retina is less sensitive to these colors, and (2) because when the sun is near the horizon the indigo and violet rays are mostly sifted out in their long journey through the atmosphere.

Another way of stating the matter is to say that at sunset each of the different colors of the spectrum forms an independent image of the sun, and that these several images are not exactly superposed, but fall as shown in Fig. 2, where, for the sake of simplicity, only three colors are considered. Thus the solar disk is bordered above and below by a fringe of prismatic colors, which, however, is not perceptible to the eye except when the latter is screened from the bright image of the sun, as by the horizon. Through a telescope Prof. Rambaut was able to see the "green flash" —and also the "red flash" at the lower limb of the sun —on any morning or evening when the sun shone in a clear sky, by simply placing an opaque diaphragm in the focal plane of his object-glass.

The duration of the flash depends upon the obliquity of the sun's path with respect to the horizon. In low latitudes it is very brief, as here the sun sets and rises nearly or quite vertically. The duration of the phenomenon increases with the latitude (for any given position of the sun in its orbit). In the neighborhood of the Arctic Circle, at midsummer and at midnight, the sun may pass so close below the horizon as to give a "green flash" lasting 12 minutes or more.

[1] *Symons's Meteorological Magazine*, March and April, 1906.

The Philosophy of Purchasing Supplies*

By Elihu Cunynham Church.†

SOME time ago I was directed to reorganize the Bureau of Supplies for the Water Department of New York City, and in carrying out the work I have attempted to formulate the principles governing the problem. Briefly stated they are: Get the right materials in correct quantities at the lowest price.

Getting the Right Materials.—Many requisitions fail to describe properly the quality of the material needed. There is a tendency to order the highest grade obtainable when the goods are not to be paid for by the man doing the ordering; this is especially true as men seem to feel that it relieves them from responsibility for any subsequent failure of the articles when in service. It is an expensive habit, and except in rare cases requisitions should be filled with articles of the standard commercial grades.

Getting the Right Quantities.—Requisitions as received must also be carefully considered to ascertain if the quantities called for are proper; for unless there is an inventory of material on hand one may easily purchase supplies of which there are plenty in stock. I have found that new orders are often based on the orders of previous years irrespective of whether materials so ordered were used and without considering that conditions and requirements have changed in the meanwhile. To this end an inventory of the property of the department is being taken and wherever possible requisitions are filled from stock on hand.

Storage and Care of Supplies.—The storage and use of all goods should also receive the careful scrutiny of the Bureau of Supplies for it is inconsistent to keep accounts of money with great accuracy, and then when the money is invested in stores pay no attention to whether they are used or wasted. Improper storage often results in excessive depreciation. Supplies should be issued in rotation; for when stores are issued in the order in which they are received no old material is left on the back of the shelf to deteriorate and subsequently be thrown out. To carry these ideas into effect storehouses are being fitted up at central points, and a number of specially trained men have been installed as store-keepers.

CONSUMABLE AND NON-CONSUMABLE SUPPLIES COMPARED.

I have also divided all supplies into two classes, consumable and non-consumable. Fuel, oil, waste, and lumber are examples of the first class, whereas tools, implements, rubber boots, etc., belong in the second group. As soon as possible it will be arranged that none of the non-consumable supplies will be issued till those they are to replace have been turned in. Thus a man cannot procure a new tool till he has returned the old one and shown that it was worn out.

Specifications.—The problem of obtaining the "right material" brings the question of specifications to the front. Multiplicity of styles and types is a disadvantage, and simplification is greatly to be desired and sought after. To this end investigations and tests are now being made to determine and establish the standards of quality to be met by the various materials purchased.

Getting Low Prices.—In order to obtain low prices a number of things are necessary. First it is essential to have as much competition as possible. To bring this about lists have been prepared giving the names of the firms making the various classes of goods, and then we notify them when we are in the market.

Supply contracts are now so drawn that goods in different groups or divisions, as determined by manufacturing specialization or trade usage, may be bid on separately; for if orders are drawn to contain goods of different classifications the bidders will be "middle men" and "commission merchants," not the makers of the wares nor the regular dealers in the various subdivisions in which supplies are customarily bought and sold.

In order to interest the manufacturers and get them to bid it is necessary to purchase fairly large quantities at a time. To do this the department now buys its supplies (except for emergencies) every three months and these new quarterly contracts contain sufficient goods in each class to enable the makers to quote wholesale prices.

Another advantage of quarterly contracts is that where goods are bought in quantities, all to be delivered to some central storehouse, the proportion of the cost chargeable to delivery becomes very small.

Every effort is made to reduce the time which it takes to canvass bids, notify the low bidders and award the contracts, for delay in this respect might cause loss and inconvenience due to possible changes in prices and market conditions.

The new methods have so simplified matters that on the average the time required after the delivery of supplies to inspect them, audit the bills and forward the bills to the comptroller for payment has been reduced from many weeks to less than eight days.—*Engineering News.*

*Condensed from a paper read before the American Water Works Association, June, 1912.

†Secretary of the Department of Water Supply, Gas and Electricity, and Acting Chief of the Bureau of Supplies, Park Row Building, New York city.

Smokeless Powder*

With Reference to Its Granular Form

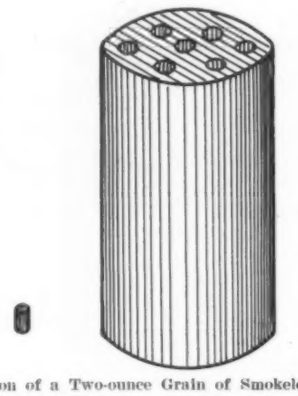
By Charles A. Junken, C. E.

CONSERVATISM is largely responsible for making smokeless powder in the form of grains. "Gunpowder has always been produced in grain and, therefore, gunpowder must still be produced in granular form," is the axiom that seems largely to govern in the production of the wonderfully-advanced propellant of today, known as smokeless powder.

The "ancient and honorable" black powder of Chinese invention, at a time so very remote that we try to forget when it really was first invented, took on the form of grains because of the method of its manufacture, and thereby became the fixed standard for all products to be used for obtaining like results. A huge mass of the elemental constituents, saltpeter, charcoal and sulphur, was made into a "cake" to be broken up, ground, if you please, into small particles that might be more quickly ignited, throughout the mass, and thus produce the enormous pressure due to the sudden production of the gases of combustion thereby evolved.

Subsequently, it became apparent to some very deep thinker on the subject that if the grains were enlarged the time of combustion would be lengthened, development of gases would be slower, and a powder might be produced which would be *safe* when ignited in the large charges required in big guns. In other words, the amount of gas developed from the combustion would be as great as before, with a propelling power of equal intensity, but the propelling force would be released at a slower rate. This was a marked step in advance, but however large or small the broken fragments of the original mass or "cake," as it was called, the broken particles still represented "grains." Hence, that gunpowder must be in the form of grains, became a fixed and immutable idea.

Some German (names are purposely omitted of the publicly-declared men who suggested innovations, because it is so hard to tell just who the original thinkers were) suggested a new formula, slightly differing from the Chinese, for the production of gunpowder, which came to be known as "Brown Prismatic" or "German Cocoa Powder." This powder, as the propelling charge for big guns, has never been excelled for uniformity. It is much to the discredit of later inventors of smokeless powder that they seem to have completely



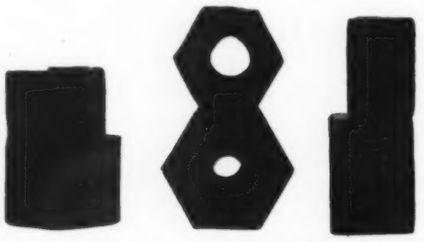
Comparison of a Two-ounce Grain of Smokeless Powder With the Proposed Quarter Charge for a 12-Inch Gun.

lost sight of the essential principle that made brown prismatic powder so absolutely uniform and regular.

For the benefit of the uninitiated, a brief description is given of the form of grain and method of building up a charge of brown prismatic powder.

A grain looks for all the world like an unfinished nut of rather rusty iron. Each grain is an hexagonal prism with a small hole through its axis of length. It measures about an inch and a half across and about three quarters of an inch in height. The hole is the truly essential good quality inherent in this kind of gunpowder, though this, as has been stated, seems to have been completely lost sight of by the inventors of ing up a charge of brown prismatic powder.

A slight digression as to what is meant by uniformity seems permissible. A uniform powder is one that will give uniform velocity to a projectile on its exit from the bore of a gun. Slight variations in the "muzzle velocity" produce great variations in range, especially at high angles of elevation. Therefore, it is apparent that projectiles must be started with a uniform velocity from round to round in order to land in the same spot in each successive round. In this wise only



Grains of Brown Prismatic Powder for Large Caliber Guns. The Left-hand View Shows the Original Grain After Being Partially Burned, and Illustrates the Action of the Powder in a Gun. The Grain is so Proportioned as to be Entirely Consumed About the Time the Projectile Reaches the Muzzle. This Kind of Powder Has Been Superseded by Smokeless.

can corrections based on observations of the barometric conditions of the atmosphere, the state of the tide, the direction and velocity of the wind, and the rate of travel of the target, be accurately taken into cognizance.

In order to obtain such uniformity, it was decreed that these uniform grains of brown prismatic powder should be uniformly placed in making up the propelling charge for the guns into which they were to be loaded. To this end, base plates of wood, to which were affixed metal rods, properly spaced, were provided. Upon these a sufficient number of *grains* of brown prismatic powder were threaded to provide the requisite size of the propelling charge. This was readily figured from data relating to the size of powder chamber, the weight of projectile and its length of travel in the bore of the gun, the limiting pressures the gun could stand, and the highest velocity obtainable under these conditions. The dimensions of such a charge being carefully ascertained, bags of suitable fabric were made to stretch tightly over the built-up charge, which was then inverted, the base-plate, with its rods, withdrawn, and the mouth of the containing sack securely closed by suitable drawing-strings.

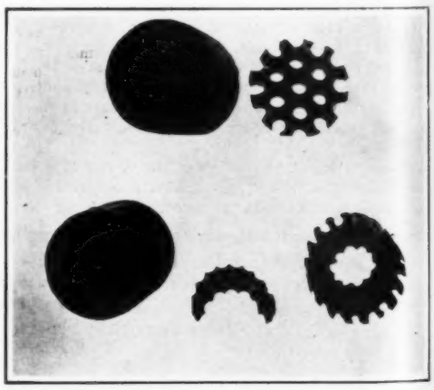
A charge thus built was rigid, presented absolute uniformity of its structure in grain and formation, and uniform results might necessarily be expected to follow. The hole in each grain was, however, the most essential factor. These holes presented a flame-channel for the uniform progression of ignition throughout the charge. In other words, each particular grain of each powder charge was ignited under as nearly parallel conditions as it was possible to attain. That these conditions are essential to uniformity, it would seem that even the lay mind would grasp. On the other hand, the uniform size of grain prescribed for brown prismatic powder was of decided disadvantage. In view of the varying elements of construction and the required variations in muzzle velocity for guns and mortars in the service of coast and field artillery and infantry and for sporting arms, it was impossible to adopt brown prismatic as a universal propellant. Imagine a sportsman trying to introduce an inch and a half grain of powder into the shell of his rifle.

The smokeless-powder men recognized the contingency relative to size of grain, but apparently have lost sight completely of the essential principle of uniformity of loading, for they dump their short and small grains into a loading-bag with a shovel. That uniformity of loading is essential is evidenced by the variations in muzzle velocity which result in range firings with recently-manufactured smokeless powders. Firings are conducted at the Sandy Hook Proving Ground under carefully prepared programmes for the purpose of computing range tables. In such firings every precaution to avoid irregularities is taken, with the essential exception of irregularity of loading. Powder charges of smokeless powder are weighed to the nicest exactitude. With sand and sawdust, projectiles are weighted to exact weight. Screens for measuring the jump are carefully placed. Five to seven observers are stationed to watch the splash of the projectile as it hits the waters of the Atlantic. Tide observations are regularly made. Atmospheric conditions are noted, the height of the battery is known, and proper corrections are applied.

After all these precautions are noted, observed and compensated for, the variations in range between successive rounds are sometimes as great as two hundred yards. On consultation of the records the reason for this wide variation is apparent. The variation in muzzle velocity between successive rounds is often as high as eighty feet per second. The cause of this is obvious.

The powder charges, carefully regulated as to size of grain, have been shoveled into containing bags in indiscriminate masses. No attention whatever has been paid to flame-channels. Each "grain" is perforated from end to end by axial holes, more or less numerous, and careful experiments have been conducted as to the best size and arrangement and number of such perforations. Discussions over this essential point and the resultant web-thickness have waxed hot, and a multi-perforated grain was adopted as necessary to perfect ignition; and there can be but little doubt as to the wisdom of the conclusions drawn, for we have become very wise in this latter generation on the subject of perfect and complete combustion of all the powder used in a propelling charge before the shot leaves the muzzle. All this, as related to the established size and structure of a *single grain*, was admirable. And then (think for a moment) these carefully prepared grains, the result of so much careful study, are tossed with a rude shovel into loading bags to the requisite weight, carefully ascertained, of the requisite propelling charge.

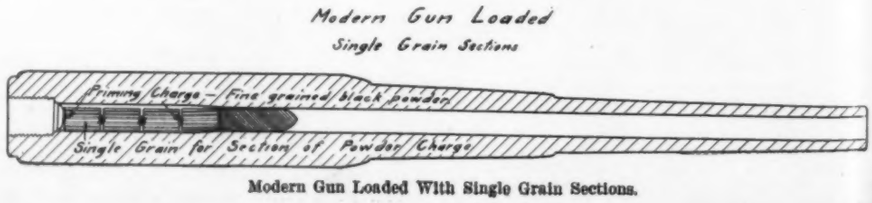
Uniformity, under such conditions, is out of the question. No uniformity can even be suggested when,



Some Samples of Entire and Partially Burnt Grains of Smokeless Powder.

in the made-up charge, flame-channels of equal uniformity are neglected. In other words, *uniformity of loading* is being entirely lost sight of.

The remedy is at any rate easy to suggest. The building apparatus employed in making up charges of brown prismatic powder is still available; but may it be suggested that a single grain, as the term still applies, be used for a complete charge for any firing arm? The only limitation imposed is the weight that can be readily handled by a single man of the gun crew in loading a big gun.


Modern Gun Loaded
Single Grain Sections
Priming charge — Fine grained black powder
Single Grain for Section of Powder Charge

Modern Gun Loaded With Single Grain Sections.

* Photographs reproduced from Notes on the Construction of Ordnance, Ordnance Department, U. S. A., Washington, D. C.

For many reasons it is essential that the "powder monkeys" of civil war times be still employed. The powder charge of a big gun should be divided into such sections as can be readily handled by a "powder monkey." Such a section should consist of *one grain* of smokeless powder—it will be noted that the term "grain" is still applied.

Such grains are readily possible. In course of manufacture smokeless powder is formed by pressure through molds. It will be just as easy to make big molds as small ones. The ballistician, after a little information derived from firing such "grains," will be able to give the exact form, size and perforation required; conveying and loading will be facilitated, no damage from remnants of partially consumed and flaming bags will result, the charge can be cleanly handled, and uniformity will ensue.

A single "grain" may weigh as much as ninety pounds. This, it must be confessed, is rather startling to the conceiver of "grains;" but "the world do move." Difficulties of manufacture are, to the writer, readily overcome. Shrinkage, warping and distortion in drying must be taken care of; that is all that is needed to secure the desired result.

What a field this opens up. A sportsman is provided with a cartridge of smokeless powder fitted with a metallic base to serve as a cap-container and gas-check. The load on his back is materially diminished. The same form of cartridge applies to all guns of larger caliber where fixed ammunition is used, and in the service of field and siege guns represents a great saving in weight of useless brass. Reloading consists in affixing another smokeless charge to the metal base, the carrying capacity of caissons being thereby greatly increased. In still larger guns, the sections of a powder charge are absolutely rigid, are lighter and easier to handle, and, most essential of all, flame-channels are provided, and absolute uniformity of combustion should result.

New Researches on Electric Discharge Phenomena*

Some Interesting Experiments With the Ruhmkorff Coil

By M. A. von Luttgendorff

THE accompanying pictures illustrate some interesting experiments made by H. G. Proumen for the purpose of studying certain phenomena of the electric discharge, which are reported in *Annales et Bull. de la Soc. R. des Sciences Med. et Natur.* In the first experiment (Fig. 1) two disks of copper, *A* and *B*, were connected with the poles of a Ruhmkorff coil. Upon the disk *B* was laid a glass plate, upon this a piece of silver bromide paper with the sensitive side up, and upon the paper, finally, a few coins. The disk *A* was then

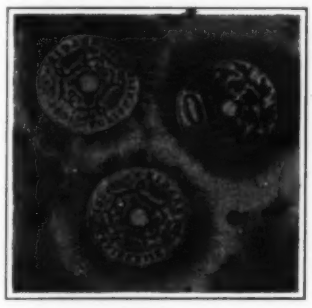


Fig. 1.

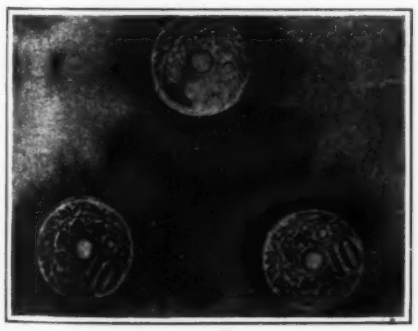


Fig. 4.

brought into contact with the coins and the current allowed to operate for two seconds. The results are shown in Fig. 1. When, instead of the plate *A*, a copper ball connected with the coil was brought in contact with a coin, the paper beneath was blackened in the manner shown in Fig. 2.

In Fig. 1 we see that the paper around each coin is blackened with radiating lines. This blackening is caused chiefly by the presence of ions due to the electric discharge. Apparently, these peculiar radiating effects are caused by the ions which impinge upon the coin and are repelled by it. The zone in which the ions repel each other is shown by a white coloration. Circles of white also appear around the black radial rings, but these white circles represent the zones of collision between the ions reflected from the coins and the ions existing between the plates. Fig. 3 shows the result of a similar experiment in which a piece of black paper was interposed between the coins and the sensitive paper.

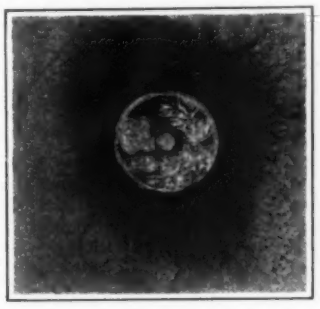


Fig. 2.

Analogous results can be obtained when the coins and the upper plate are separated by a small space. In this case, it is observed that the crown of rays becomes blacker as the distance between the plate and the coins increases. This result is easily explained by the fact that the greater space contains a larger number of air molecules, and, hence, of ions. The field of the electric discharge, therefore, was greatly increased by this slight separation of the plates.

Fig. 4 shows the result of a slightly different arrangement in which a large coin rested upon the edges of three smaller ones. No black paper was used in this experiment. As the upper plate touched the large central coin directly, while it was separated from the smaller coins by the thickness of the large one, the pattern of the small coin is blacker and distinct, while both the pattern and the surrounding ring of the central coin are less sharp. A repetition of the same experiment with a longer application of the current is illustrated by Fig. 5.

In regard to the patterns of the coins, certain differences are apparent. In Fig. 1, for example, the raised parts of the pattern are black, while in Fig. 2 they are white. Proumen explain this difference by the dependence of the effect upon the distance of the coins from their environment. If the coins are in contact with the sensitive paper, so that there is no air between the paper and the metal, the raised parts appear white. On the other hand, the impression is darker in proportion to the mean distance between the paper and the surface of the coin, i. e., to the number of ions reflected. But although the raised part of the coin is nearest the paper, it produces a darker impression because it is the seat of the greatest electric tension.

Fig. 6 illustrates an experiment in which a small copper fork instead of a coin was placed in contact with the sensitive paper. Fig. 7 illustrates the same experiment with the black paper interposed. Fig. 8 illustrates an experiment in which Proumen endeavored to eliminate the action of the ions even between the black paper and the sensitive paper. Upon the lower copper plate, connected with one pole of the coil, a glass plate was laid. This was covered with silver bromide paper and the latter with black paper. The other pole of the coil was connected with a metal point which was inclosed in a balloon of goldbeater's skin, inflated with air. The point, thus covered, was brought into contact with the black paper, which was pressed close against the entire surface of the silver paper by the pressure of the balloon. The black impression produced was probably caused by ions traversing the goldbeater's skin and the black paper, while the white spot indicates the actual position of the point.

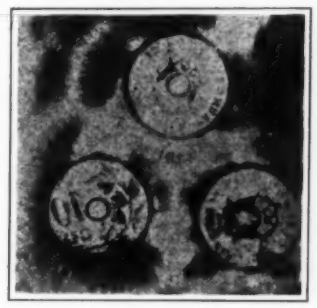


Fig. 3.

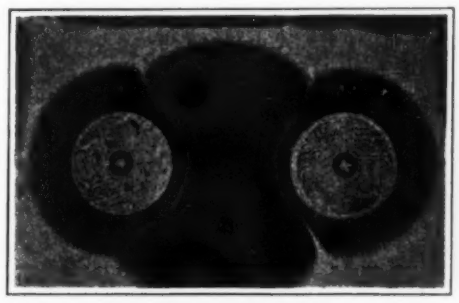


Fig. 5.

This result, which may be explained by supposing either that no ions flowed from the point, or that such ions produced no effect, appears to prove that the phenomena of the electric discharge are due to ionization of the surrounding dielectric. In this figure, also, the white circle surrounding the points is perceptible.

Similar effects can be obtained with a single pole by connecting the metal point with one pole of a transformer of high voltage.

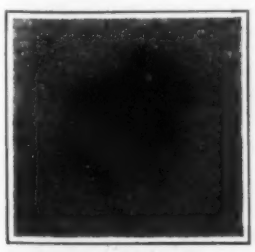


Fig. 6.

Fig. 7.

Fig. 8.

* Abridged translation from *Die Umschau.*

Manufacture and Treatment of Steel for Guns—II*

An Industry of About Thirty Years' Standing

By General L. Cubillo

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 1912, page 128

III. HEAT TREATMENT.

Before proceeding further, it will be convenient to consider, at this point, the heat treatment most appropriate for gun steel.

The steel, having been cast in a mold of truncated cone shape, required, of course, to be forged, in order to give to the gun or part of the gun the required form, which is always that of either a hollow or a solid

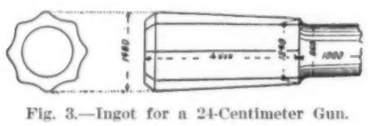


Fig. 3.—Ingot for a 24-Centimeter Gun.

cylinder, of varying length, with different diameters outside, and sometimes also inside. The annealing after the forging, the hardening—or hardenings, if it is necessary to harden more than once—and the subsequent tempering or temperings, constitute the series of heat treatment processes given to the steel for gun construction. Forging is not only necessary for giving the required form, but principally to change the crystalline structure of the large and medium-sized castings into one of finer grain, almost amorphous, which is essential for the best development of the physical and mechanical properties of a given steel for ordnance purposes. But as it is possible to obtain from a given steel, simply by heat treatment, without the aid of the press or of the hammer, physical and mechanical properties equal to those conferred by forging, it is only natural to ask if the forge is absolutely necessary, and whether, instead of casting ingots of the usual shape, it would not be possible to cast pieces of approximately the final form, and subject them afterward to the heat treatment capable of modifying the texture developed by the cooling after the casting. This is a question which has been very much discussed for many years, and opinion seems on theoretical grounds to be in favor of the suppression of the forge, but on practical grounds the forge is retained, and there is no indication whatever that it is likely to be dispensed with.

The manner of fixing the amorphous structure obtained by heat treatment is to cool the piece very quickly. For thirty or more years these facts appear well established, yet the specifications of all the armies and navies of the world continue to require the use of the forge in the manufacture of gun steel, notwithstanding that eminent metallurgists have demonstrated the possibility of making very good pieces for gun construction without the aid of the forge. The tests were certainly made with small pieces many years ago, but an enterprising firm in Sweden now makes guns up to 24 centimeters caliber without forging. In 1882 Mr. Pourcel, in a paper read before the Iron and Steel Institute, described the series of operations which constituted the whole process at the Terre-Noire Steel Works in the manufacture of steel hoops for 4-inch guns. These hoops must, of course, satisfy the same specifications as those required for the forged metal. After casting the steel with the necessary additions of ferro-silicon for freeing the ingots from cavities and securing a perfectly sound metal, a heat treatment was given to the hoops, which consisted in heating them to a yellow heat and hardening them in an oil bath of fixed weight. After being cooled in the liquid they were afterward reheated to a temperature which varied from light cherry red to a dark red cherry red, in accordance with the chemical composition of the metal. The hoop was then cooled in a bath of the same liquid, where it remained until it was perfectly cool. By the first hardening the crystalline grain of the metal was transformed into a finer and homogeneous grain. The second hardening confers on the pieces molecular equilibrium corresponding to their chemical composition.

The result of these two operations was a true hardening, inasmuch as the piece was heated to a higher temperature than that of the transformation point, and by this the size of the original grain was changed, and the new structure fixed by subsequent cooling in a large quantity of oil.

The second heat treatment, also called hardening by Mr. Pourcel, was, rather than a hardening or annealing, a true tempering, which caused the disappearance of the strains originated by the hardening, and increased the ductility, which had been lowered by the first operation. Sometimes it was necessary to repeat the two operations, if the tenacity of the metal was less than that required by the specifications, or only the second if the ductility obtained was less than required. Mr. Pourcel had some doubts at that time if this process, applied to guns of a caliber larger than that of 4 inches, would give the same excellent results. His conviction inclined him to take the affirmative side of the question. Undoubtedly he had thought the subject out in a logical manner, and it is not easy to understand why such ideas as these, so well grounded, have not been adopted by metallurgists. The Swedish Steel Works, the Aktiebolaget Bofors Gullspang, for many years has been successfully applying steel as cast to the construction of guns. Working systematically, and passing gradually from the simple to the complex, it began by producing field guns, followed by the fortress guns, and finally essayed the manufacture of coast and navy guns, commencing with a quick-firing gun of 15 centimeters in caliber. The United States of America even used a gun of this type, the trials of which were commenced in 1902, and gave exceedingly good results.

Recently, the author has ascertained that the Bofors Steel Works has constructed guns of 21 centimeters and 24 centimeters, whose elements have been simply cast and afterward subjected to heat treatment. Of course, the elements for the field and fortress guns are also subjected to proper heat treatment. These are facts the importance of which it is impossible to deny. They afford evident proof of great advance in the way of applying heat treatment alone without forging the elements of guns. The author thinks, however, that it is no easy matter to cast 10-inch and 12-inch gun tubes 50 calibers in length, molding them in a refractory mold.

There is another reason against the acceptance, by governments, of this process of manufacture. It may happen that, despite all the precaution and care taken in the finish and casting of the elements in order to obtain pieces absolutely free from cavities, a cavity may occur in the thickness of a tube without being detected during the mechanical work, and may cause the bursting of the gun when firing.

Hardening and Tempering.—If forging is necessary, or presumably necessary, in order to obtain first-rate elements for the manufacture of the guns, the hardening process is also necessary for the tempering. To obtain these properties in the highest degree must be the supreme object of the metallurgist. The author, during many years' experience in the manufacture of steel, both by the crucible and open-hearth processes,

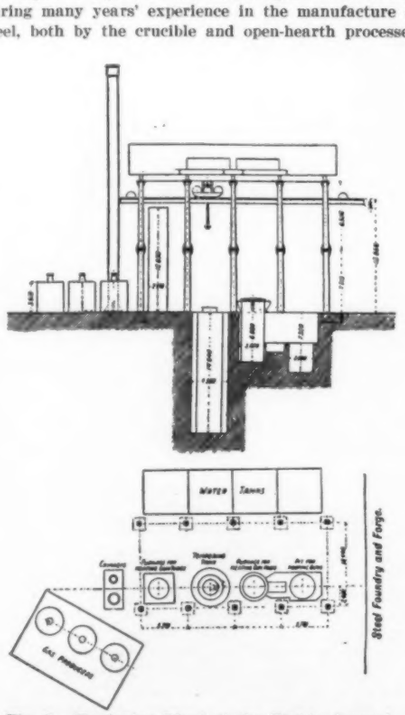


Fig. 5.—Hardening Plant at the Trubia Arsenal.

for 24-centimeter guns of 45 calibers in length, has found that however well conducted the forging, the transformation of the crystalline structure into one of amorphous, or fine grain, is only obtained in the highest degree—if the forging is not completed—by hardening and tempering, and sometimes more than one and more even than two such operations. As it is not the chief aim of the hardening—in semi-hard steel of the type used for gun construction—really to harden the

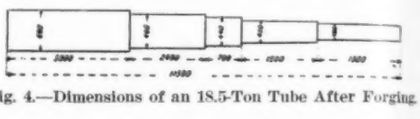


Fig. 4.—Dimensions of an 18.5-Ton Tube After Forging.

metal, and as it is easy to obtain the required mechanical qualities by forging only—followed by an annealing—it would seem that the hardening might be dispensed with. However, as many years ago hardening in oil was introduced with excellent results, the process was retained and formed part of the specifications. The study of iron-carbon alloys has shown the great advantages that can be derived from an adequate heat treatment of the steel.

The most important point in forging is to fix the limits of the temperature within which it is possible to conduct it. The highest, of course, must be the temperature at which the cohesion of the grains of metal begins to weaken and the grains to separate; this last action is due also in part to the gas evolved from within the mass. The generally admitted hypothesis is that this gas is carbon dioxide formed by the oxygen passing through the metal and combining with the carbon, though it is possible that carbon monoxide and other gases, such as nitrogen and hydrogen, are also given off. When a steel is in this state it is said to be burnt, a condition which is chiefly distinguished from the overheated state by the separation of the grains. To this can, perhaps, be added the great thickness of the ferrite network, which is found when the steel cools through the temperature interval Ar^3 Ar^2. It can be said that the upper limit of temperature for forging the steel for gun construction is between 1,100 to 1,000 deg. Cent. The lower limit must be that of the transformation of the metal, as below this temperature the structure is not changed. This is the natural and logical limit; but some authors, especially Tschernoff, think that forging at lower temperatures is convenient. But certainly Tschernoff would find it difficult, and even impossible, with the means at his disposal when he wrote his celebrated paper, to forge the large mass required for great guns at temperatures below the transformation point.

Coming now to the practical aspect of forging large ingots for gun construction, it must be emphasized that it is necessary to heat them very carefully and slowly. If the temperature of the furnace, when the ingots are introduced, is rather high, it is better to pre-heat them. Certainly, the temperature of the furnace is suddenly lowered by the introduction of cold ingots, which naturally take a great part of the heat lost by the furnace; but this heat, taken up suddenly, causes a sudden dilation of the outside of the ingot with the natural consequence of cracks, and it may occasion the breaking of the ingot across. This happens especially if the metal is somewhat hard. The two reheating furnaces for the great forging press at Trubia are of the Whitworth type. Their doors are worked by hydraulic power. The largest ingots until recently, forged at Trubia, were 42 tons weight, suitable for the forging of the tubes and other elements of the 24 centimeters and 45 calibers. As an instance of solid forging, that of the *A* tube for the 24-centimeter gun may be taken. The ingot on being taken out of the mold was 16 feet 6 inches in total length, of which 13 feet corresponded to the pyramidal part, cast in the metal mold, and the other 3 feet 6 inches to the conical part cast in the refractory material attachment. The diameter at the two bases of the trunco-pyramidal part was respectively 4 feet 10 inches and 4 feet. The main diameter of the truncated cone part was 2 feet 8 inches. (See Fig. 3.) The ingot free from all cracks, and reduced to a diameter of about 2 feet 8 inches by the previous forging, was put in the furnace, where it was heated carefully and very slowly during thirty hours, which is a sufficient time for the whole mass to become well

* Iron and Steel Institute.

and uniformly heated throughout. The temperature, as already stated, was 1,100 deg. Cent. approximately, and the forging operation is suspended at 700 deg. Cent., when the ingot is put into the furnace again. The operation was finished in three heats, and the time taken to complete it after the first heating was fifteen hours. The tube weighed 18.5 tons after forging, and its dimensions are given in Fig. 4. For the hollow forged tubes and hoops, 40-ton ingots are also employed. From each ingot two *B* tubes are forged. The operation of removing the cracks and also of the previous forging are the same as those practiced with the ingots for the *A* tubes. Afterward the blocks are sent to the large boring machine supplied by Sir William Armstrong, Whitworth & Co., where they are bored from both ends at the same time to a diameter of 1 foot right through. When this operation is finished, the ingot is cut into two halves. The reheating is performed in the same furnaces and conducted with the precautions already described in the case of the *A* tubes. The duration of the first heating is thirty hours, and the first operation practiced is that of enlarging the bore in a Whitworth drawing press. When the operation is finished throughout the length of the tube, the latter has a larger diameter and less thickness than at the beginning of the operation. The tube then goes again to the furnace, and after careful heating the forging is continued, and it is again stretched on mandrils of different diameters. The full operation involves four reheatings, and the total duration is from thirteen to fourteen hours, the final dimensions of the tube being: Total length, 17 feet 2 inches, and outside diameters 2 feet 4 inches, in a length of about 20 inches, and of 2 feet 3 inches in the rest of the piece. The inside diameter is 14 inches. The great hoops are forged by means similar to those employed with the *B* tubes. Sometimes when the ingots from which they are obtained are not very long, the hole for the mandril is punched in the press after being carefully reheated, instead of being bored in the machine. This operation is made in one heat, the hole being driven by a conical steel tool which enlarges and lengthens the hole. When half of the ingot has been treated, it is turned and the operation repeated on the second half. It is preferable to bore the ingot, because in this manner the steel of the central part, with a chemical composition distinct from the rest of the ingot due to segregation, is eliminated. Forging after boring must be practiced—in preference to forging the solid ingot—when possible, because the action of the press is more energetic in the first than in the second case, the press acting on less thickness of metal. With hoop No. 1 for a 24-centimeter gun, forged hollow, the following notable tensile results were obtained after the full heat treatment. At one end of the hoop, the mean result of three test bars was 52 tons per square inch tenacity and 17 per cent elongation measured in 4 inches, and at the other end 54 tons tenacity and 17 per cent elongation, conditions better than those ordinarily specified for nickel gun steel.

Annealing After Forging.—This is an indispensable operation in the manufacture of steel for guns. If it were possible to finish the forging of a piece in one heat only and in such a manner that the whole piece was finished at an even and correct temperature, then, in this case only, the annealing operation could be dispensed with. Some think the operation superfluous, as the piece must be heated to a higher temperature for the hardening process or to a temperature at least equal to that required in the annealing. But forging cannot be conducted in the ideal manner just described, nor is it possible, in the last period, to heat the *A* tubes for large guns uniformly throughout their length. The lack of uniformity in the finishing temperature requires that the pieces should be annealed before passing to the machine shops, to be prepared for the hardening process. After annealing the metal will be in the best possible state for the turning and boring operations, and the pieces are less likely to suffer deformation during handling. In being reheated preparatory to hardening they retain their shape better, and in taking them out of the furnace for cooling they are less likely to bend and they undergo less deformation in the process of hardening. The slight deformation in the finishing mechanical operations is also avoided, and exposure to direct sunlight has less effect. Owing to these special circumstances, the Government of the United States specify, in the construction of howitzers, that the shops of the Niles Company, in Hamilton, Ohio, must be always at the same temperature. At Trubia, for the annealing after forging, the same furnaces are used as for the hardening. The operation is conducted very carefully, the temperature in all parts of the furnace, and of the piece, being measured with a Le Chatelier pyrometer. When furnace and piece are at the proper uniform temperature, the gas is shut off, and the piece cools slowly in the furnace. Of course, the annealing temperature must be above the transformation point. The elements for field guns are annealed in a special furnace. Taking into consideration their small mass, they are not individually annealed, but eight or ten are put into the furnace at a time. They are heated to 900 degrees very carefully, and after reaching this temperature they are slowly cooled. The author thinks that the advantages obtained by annealing, after forging, are more marked in the elements for the field guns.

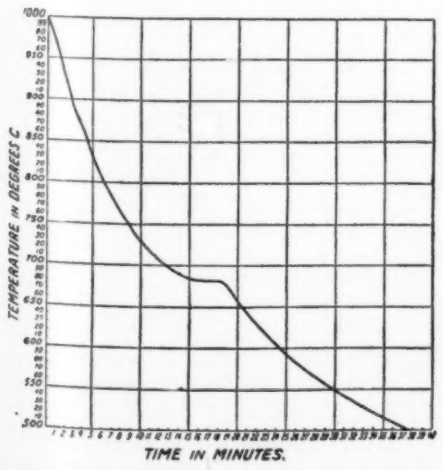


Fig. 6.—Cooling Curve for Carbon Gun Steel.

IV. HARDENING AND TEMPERING.

The author has already endeavored to demonstrate the necessity of subjecting to a certain heat treatment the steel for gun construction. This heat treatment comprises one or more hardenings and temperings as required in order to satisfy the specifications; and the heat treatment must comprise precisely the hardening and tempering. It is also well to insist on calling the second operation tempering and not annealing, because in preparing the pieces for this operation they are heated to a temperature below the transformation point. If they were heated to a temperature above that point and then cooled slowly the structure of metal created by the hardening process would absolutely disappear. Perfect hardening indicates in the metal a state of unstable equilibrium at ordinary temperature, because this state is that of equilibrium at a temperature above that of the transformation point. Mr. George Ede claimed that the hardening in oil for the elements of guns originated in England at Woolwich Arsenal. The process originated in consideration of the benefits derived from the hardening in oil of hard steel for tools, and in treating the milder steels employed in the manufacture of guns in the same way it was found that the mechanical properties were improved. Tschernoff, in his celebrated paper on the "Working of Steel," says that for securing uniformity and fine grain it is necessary, after finishing the forging, to reheat the piece to a temperature above the point *b*, which is that of the transformation in his scale, and then to fix the amorphous texture by rapidly cooling it; this amorphous texture will be more surely obtained, the rapidity of cooling being the same, the less the point *b* in the reheating be exceeded.

Tschernoff and Woolwich Arsenal coincide in the treatment after forging to be given to the elements for gun steel, and this has led perhaps to the process being adopted by some manufacturing firms in other countries. At the Krupp works the elements for guns are said not to be hardened and tempered. The author has explained in another part of this paper the reasons why the metal must be subjected to heat treatment, and it is not necessary to repeat them here. In England and in the United States oil is exclusively employed as a refrigerant liquid; in France and Spain (Trubia Arsenal) water is used. Between hardening in oil and hardening in water, the temperature, always above that of transformation, being equal, the difference is very considerable, owing solely to the rapidity of cooling. In accordance with the remarkable work of Le Chatelier, which forms a very interesting paper in the *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, No. 9, Vol. CVI., there is a well-marked difference in the rapidity of cooling a piece in water or in oil. This was well known from the time hardening was first practised, but Le Chatelier measured mathematically the rate of cooling. He operated with very small pieces, and took into consideration the extreme interval of temperature, which must be rapidly passed for realizing the hardening. Knowing that the recalescence phenomenon is never produced on cooling to a temperature superior to 700 deg. Cent., and that the tempering is not influenced by temperature down to 700 deg. Cent., he only took into consideration in his experiments the time spent in passing from 700 to 600 deg. Cent., which time, all the remaining conditions being equal, gives a very accurate notion, almost mathematically exact, of the rapidity of cooling, and therefore of the energy of the hardening. The central part of the sample, hardened in pure water, employed five seconds in passing from the temperature of 700 deg. Cent. to that of 600 deg. Cent. In the oil hardening for passing the same interval forty-three seconds were required, that is, the time was seven times longer than with the pure water. It must be said that in this experiment of Le Chatelier with oil, the rapidity of cooling was much less in the interval of 190 to 100 deg. Cent., in which interval thirty seconds were spent. It is natural that this happens with all the refrigerant liquids, but in oil it is much more marked, and the explanation is, according to Le Chatelier, that during the operation the oil is decomposed and the gaseous bubbles cause a circulation of the liquid, which must cease at the end of the cooling. From these experiments, confirming by a scientific method all that was known, it is possible to state what will be the difference of hardening which two elements heated to the same temperature and cooled in two liquids, both also at the same temperature, should take. If the elements hardened in both liquids were intended for large guns, and if they should possess great thickness, there would be sufficient reasons for thinking that none of the pieces would possess, at the ordinary temperature, the structure which it possessed at the beginning of cooling. But surely the piece hardened in water should be the nearest to this structure. Benedicks, in a paper recently read before this institute, has made experiments on hardening in a manner very similar to that of Le Chatelier. He says that the most important factor in the rapidity of cooling is neither the conductivity nor the specific heat, but the latent heat of vaporization of the liquid. The specific heat has a secondary influence, and it is possible to dispense with the heat conductivity. The necessary conditions for obtaining from a given bath an efficacious hardening are as follow:

1. A high latent heat at vaporization.
2. A low temperature, in order that the vapor bubbles, generated in the surface of the metal, might be easily condensed in the ambient liquid. Whatever may be the predominant factor in the rapidity of cooling, the hardening in water will always be more energetic than the hardening in oil. Therefore, there is no doubt that the hardening in water will require a subsequent tempering, more energetic at a higher temperature than would have been necessary if the hardening had taken place in oil, in order to enable the metal to stand the tensile and shock tests specified. Really the hardening temperature must be higher than that of the transformation point, so that in submerging the piece in the refrigerant liquid the cooling might begin when the steel is yet at a higher temperature than that of the transformation. At the Trubia Arsenal, in the hardening of the elements for gun construction, water, as already mentioned, is employed as refrigerant liquid. The hardening plant is shown in Fig. 5. The reheating furnaces are vertical, and are heated by gas from three Dowson producers. The large furnace is capable of taking pieces 40 feet in length, and has four inlets for the gas, regularly spaced. It is built upon the ground floor, and, as is natural in these conditions, the tubes are manipulated through a lateral port, hydraulically. The second furnace is of greater diameter than the first, and its length is 26 feet. It is intended for the reheating of the *B* tubes and hoops, also for the tubes of the medium guns up to 6 inches caliber. The water tank is situated between the two furnaces, and has the dimensions stated in the drawing. The water at the time of the cooling has a temperature of 20 deg. Cent. A 35-ton overhead traveling crane is driven by a rope worked by a steam engine, and serves the whole of the hardening shop. When this plant was installed twelve years ago the intention was to use oil as a refrigerant liquid, as was the practice at Trubia with all

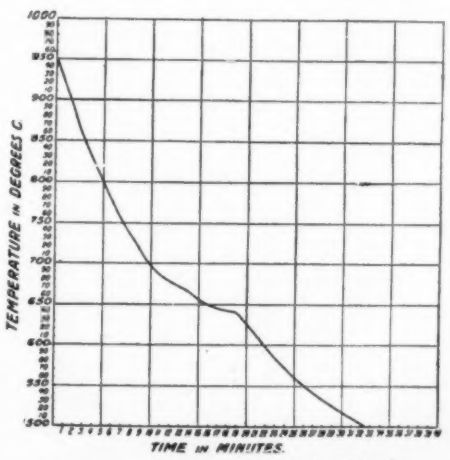


Fig. 7.—Cooling Curve for Nickel Steel.

the guns manufactured before that date, which did not exceed 6 inches caliber. In accordance with this idea, four tanks capable of containing more than 100 cubic meters of oil were conveniently installed at the top of the building, under the roof, and another four tanks of the same cubic capacity were installed at the outside of the shop, and on a level lower than the ground floor. The hardening tank is in communication with the higher and lower tanks by means of a system of pipes which are worked by the necessary pass valves. A steam pump can elevate the liquid, when it is cooled, from the lower refrigerant tanks to the higher, and during the hardening it is possible to maintain a constant current of oil in such a manner that that of the hardening tank should not take a temperature so high that the piece instead of being hardened is annealed. As is seen from the drawing, the capacity of the shop is limited to the hardening of elements for 10-inch guns and 45 calibers in length.

The measuring of the temperatures is done by the aid of the Le Chatelier thermo-electric pyrometer, registering the temperature of the tube or hardened piece at different points in order to distribute the heat in such a manner that the temperature may be uniform. Undoubtedly the best method is that followed at Woolwich Arsenal, with the long tubes for the 12-inch guns of 45 and 50 calibers, where four or five Le Chatelier pyrometers are installed, with registering apparatus, and regularly distributed all along the tube; that is both convenient and necessary when operating with tubes for guns of 54 feet in length, or perhaps more, with the excess length left at both ends for the test pieces. It is really very difficult to heat uniformly the long pieces of variable thicknesses, and therefore to harden them. The difference of operating as physical experimenters do in their laboratories with samples of some grammes weight, and of dealing with 15, 20, 25 and 30-ton pieces, as is the daily practice of the manufacturers of gun steel, is enormous.

If tension or compressions have been produced the layers of metal must be distended or compressed. Knowing the tensile characteristics of the metal, it is very easy to measure the intensity of the tensions or compressions, as they are of a purely elastic character, and it is possible to plot a diagram representing the variation of tensile strength in terms of thickness of the piece. In the ordinary practice of conducting the hardening operation in the tubes intended for gun construction the result generally is that the outside surface is compressed, that is to say, the contrary of what must be most convenient for the strength of the gun. With hardening in water, and dealing with carbon steel of 0.5 per cent, the tempering operation is absolutely necessary. Even when the piece has been heated and hardened with absolute uniformity, and the elastic tension caused by the hardening should be the most suitable for the strength of the gun, the tempering of the piece would be absolutely necessary, because the hardness due to the hardening would make it very difficult, if not impossible, to machine the piece in ordinary conditions of work, and the tensile, bending and dynamical properties would not be in accordance with the specifications. In hardening in oil, in nearly all cases, tempering at a very low temperature, in order to cause the disappearance of the light stresses originated, is sufficient, but in water hardening, and with metals of 0.5 per cent of carbon, the tempering temperature will be near that of the transformation point.

Ordinarily, that necessary for obtaining the best tensile properties is about 600 deg. Cent. It is clear that if these properties, after the heat treatment, are deficient from those specified, or lower than those required, it would be necessary to submit the piece to fresh heat treatment, raising the temperature of hardening and keeping constant that of tempering, or the same result can be obtained by giving the piece a new hardening at the same temperature and lowering that of tempering. If, on the contrary, the tenacity were higher and the ductility less than required, the results can be rectified by giving the piece a new tempering at a higher temperature.

COOLING CURVES AND MICROSTRUCTURES.

Even though the cooling curves of different types of steel are well known, the author believes it useful to give in this paper those of both types of artillery steel, carbon and nickel steels—Figs. 6 and 7—the latter being employed in the manufacture of field and medium guns. Owing to certain difficulties at the Trubia laboratory, it has not been possible to obtain the curves of both steels from the liquid state. The range of cooling is therefore from 1,000 to 500 deg. Cent. for ordinary steel, and from 950 to 500 deg. Cent. for nickel steel. Within this range are found the transformation points, so important for the proper treatment of the metal in all the heat treatment operations. Observing first the cooling curve of the ordinary steel, it is seen that the cooling is generally in accordance with the well-known Newton's law, and that the curve has only a well-marked point Ar_1 at 684 deg. Cent. At this temperature the curve is converted into a horizontal line for a length of 20 millimeters, indicating 200 seconds, or 3 minutes 20 seconds. The temperature is therefore constant during this period, indicating complete equilibrium of the two component systems, iron-carbon. This is the range during which the solid solution or martensite, stable at a temperature above 684 deg. Cent., is transformed into ferrite and pearlite constituents, with less than 0.89 per cent carbon, stable at a temperature below 684 deg. Cent. for this particular steel. Certainly it would not have been difficult to calculate the heat of transformation of this steel, taking into account the weight of the sample and its specific heat. From the transformation range the rate of cooling diminishes, in accordance also with Newton's law. Nickel steel shows also a small point of transformation at 656 deg. Cent, the horizontal not being as well marked as in the curve of the ordinary carbon steel. All that has been said on behalf of this is applicable to ternary nickel steel.

Trade Notes and Formulæ

Dead Black Paint for Iron and Steel.—Chloride of bismuth, 1 part; chloride of mercury, 2 parts; chloride of copper, 1 part; concentrated hydrochloric acid, 5 parts; water, 50 parts; alcohol, 5 parts. To insure success, the article to be blackened must above all be perfectly clean and free from grease, the object is then dipped in the fluid, or it is applied by a brush. After it is dry, it is placed for a quarter of an hour in boiling water. If the color is not as dark as desired, the operation is repeated.—*Neueste Erfindungen und Erfahrungen.*

Cleaning Copper Plate Engravings.—Wash the sheet on the front and back sides by means of a soft sponge or brush, with water, to every 1,000 parts of which 40 parts of carbonate of ammonia have been added, and rinse the sheet off with water. Then moisten it with water, to which a little wine-vinegar has been added, rinse again with water, in which a little chloride of lime has been dissolved, and dry in the air, preferably in the sun. The sheet will be perfectly clear, without injury to the print.—*Neueste Erfindungen und Erfahrungen.*

Incandescent Lamp Varnish.—The dipping varnish, used for incandescent lamps, according to the *Werkmeister Zeitung*, consists either of solutions of resin in amyl acetate or of alcoholic solutions of collodion. There is nothing to prevent individual preparation of such varnishes. Some preparations are certainly patented, but the patents mostly relate to the employment of certain solvents, for instance, dichlorhydrin and epichlorhydrin. The principal thing in making such a varnish is the employment of as volatile a solvent as possible, so as to insure quick drying. The color is produced by the addition of coloring substances, especially aniline colors. The solution of a resin is as a rule effected by forcing a flannel bag into the neck of a bottle containing the solvent selected, it is then filled with pieces of resin and the bottle well closed. By this means the solution is effected with fair rapidity, and in many instances filtration avoided. Some resins, however, do not dissolve clear and these are subjected to filtration through a fine meshed sieve, provided at the bottom with a flannel or linen covering. On this is placed a layer of fine, well-washed white sand, then two or three sheets of filter paper, another layer of sand, and again filter paper and sand. After filtration the filter can be washed with pure solvent. Where collodion or celluloid is used as the starting material, it is best to proceed by dissolving 5 parts of celluloid in 50 parts of alcohol, finally adding 5 parts of camphor; or 5 parts of celluloid are dissolved in 50 parts of amyl acetate, or 25 parts of amyl acetate and 25 parts of acetone. As regards the concentration of these varnishes, they must not be too thick, but must rather be fairly thin. The varnish can readily be brought, by the addition of solvent, to the desired concentration, as determined by experiment.

Metal Coatings by Rubbing.—The processes of coating metals with coverings of other metals have increased of late. More especially rubbing processes, are advertised more or less and claim to furnish a substitute on a small scale for costly plating by fire liquifying or electrotypic methods. All, however, constitute but an imperfect substitute and will hardly be able to supplant the old, well known and approved processes. Nevertheless, they merit some attention, and will find adoption where infrequent use prohibits the installation of costly apparatus and mechinery. For this reason, says *Das Techniche Echo*, we propose to devote brief attention to some of these processes. First may be mentioned the galvanite process of the Deutsche Galvanit-Werke, of Hamburg, according to which metal objects, by rubbing on a powder with the aid of a wet rag, can, in the shortest time be tinned, zinc-coated (galvanized), nickel-plated or silver-plated. A similar effect, also by the formation of small galvanic elements may be accomplished according to the following direction: Iron can be nickeled by first producing on the iron a thin coating of copper, by rubbing over it a solution of 20 parts sulphate of copper in 100 parts water and 5 parts sulphuric acid. Then, with a rag, rub on a solution of 6 parts nickel, 3 parts tin and 1 part iron in 100 parts hydrochloric acid and 3 parts sulphuric acid. If finally, the object is rubbed off with a rag dipped in finely pulverized zinc, a deposit of nickel will be formed on the copper. This nickel coating can be thickened by a repetition of the two last-described processes. Silver-plating can be accomplished, according to a new German process, by dissolving freshly precipitated chloride of silver in a solution of hyposulphite of soda (1.1 parts to 10 parts of water), adding 0.180 part of sal ammoniac to this solution and stirring in 800 parts of fine washed chalk. This mixture is rubbed on the article to be silver-plated until it dries, and a bright deposit of pure silver will be obtained.

Transparent White Clock Dials.—Glass mixture: Sand, 100 parts; red lead, 120 parts; potash, 30 parts; bone ash, 14 parts; borax, 4 parts; oxide of tin, 9 parts, and arsenic, 4 parts.

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Table of Contents

PAGE

The Earth's Atmosphere.—By Arthur W. Ewell, Ph.D. —3 illustrations 136

A Rhine-North Sea Canal.—By Our Berlin Correspondent.—2 illustrations 137

Xochimilco and Its Lake of Gardens.—By Carl Hawes Butman.—5 illustrations 138

Porous Metals.—By the Berlin Correspondent of the SCIENTIFIC AMERICAN.—4 illustrations 139

A Review of the Physics of Light.—II.—By Prof. Silvanus P. Thompson 140

The Cost of a Superfluous Language 140

The Royal Institute of Public Health 140

The Centenary of the Krupp Works.—By Dr. Alfred Gradenwitz.—4 illustrations 140

The Use of Acetylene.—By Prof. Vivian B. Lewes. 140

The "Green Flash."—2 illustrations 140

Smokeless Powder.—By Charles A. Junken, C.E.—6 illustrations 140

New Research on Electric Discharge.—By M. A. von Luttgendorff.—9 illustrations 141

Manufacture and Treatment of Steel for Guns.—II.—By General L. Cubillo.—5 illustrations 142

Trade Notes and Formulæ 144

31, 191

a solution
water and
rub on a
part iron
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PAGE

Ph.D. 130

spond- 131

Hawes 132

of the 133

f. Sil- 134

..... 135

..... 136

Alfred 136

..... 138

..... 139

.E.— 6 140

. von 141

—II.— 143

..... 144